M.E. 4182 DESIGN PROJECT
Professor: Brazell
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THE LUNAR KINEMATIC HITCH

Presented by group 6

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GROUP 6

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A. Abstract

The analysis and design of a kinematic hitch for lunar applications are presented in detail.Provisions for operation in the space environment and automatic controlling devices are included.A brief cost analysis is presented.Safety precautions and failure modes are examined.Alternative designs are also discussed.

B. Problem Statement

Background

This hitch is designed to be used at a lunar constuction site.It has the capabilities to pull implements which both remove and transport soil.When digging implements are being pulled ,it is important that they folllow the contour of the terrain.A kinematic hitch seemed to be the best answer to this problem.The hitch must also operate in a lunar environment.

Performance Goals

1) Hitch line of action must pass through the rear wheel axle of the tractor in a range of plus or minus fifteen degrees (countour following).
2) Hitch must be free to rotate in the horizontal plane.
3) Hitch must have an adjustable pitch.
4) Hitch must have lifting capability.
5) Hitch must have automatic means of changing implements.

Performance Specifications

1) Hitch must countour follow in the range of plus or minus fifteen degrees.A four bar design should employ at least three precision points
using Chebychev spacing.
2) Hitch lift must correspond to a rotation of at least fifty degrees to assure clearance.
3) Hitch freedom of rotation in the horizontal plane must be plus or minus fiteen degrees.
4) Hitch must be designed to withstand a maximum drawbar pull of approximately four thousand pounds on the basis of using a Caterpillar 910.

Cost Goals

1) Hitch must be constructed of materials with high stength to weight ratios to reduce transportation costs.

2) Hitch should utilize as many standardized vendor parts to avoid un- necessary tooling costs.

Time Goal

Design completion date: Monday,June 3,1985.

C. Detailed Decription

Physical Decription

This hitch is a kinematic four bar designed to contour follow the terrain on which it is used.The stationary linkage of the ststem is approximately two feet long across the back of the tractor.The lower link is constructed of I-Beams and a cross pattern between them to stabalize the hitch during a torsional strain.The upper link is composed of two hydraulic cylinders which give the hitch the feature of contour following.The coupler link is composed of the tongue which the implement will be connected to.The tongue is fitted with a dual hydraulic actuator used for automatic hitching.The tongue also has a hydraulic cylinder muonted on it to dampen the movement in the horizontal direction.Another hydraulic cylinder is mounted from the frame of the tractor to the center of the cross section of the lower linkage of the four bar to give the hitch lifting capabilities.All connections consist of a pin joint securred with a cotter pin.Each joint is fitted with a ceramic bearing to reduce wear on the aluminum parts.For a more detailed description of the hitch,see the drawings in the appendix.

All parts of the kinematic hitch,except the bearings,will be made of Aluminum 2218,which is a aluminum-copper-nickel-magnesium alloy used mainly in aircraft and jet engine coponents.This alloy is composed of 4 %copper,2% nickel,1.5% magnesium,and the remainder is alunimum.The alloy retains good tensil and yield strengths at elevated temperatures.Increased stregth and ductility can be obtained through age hardening and heat treatment.The material has good machineability characteristics and can be forged readily.The weldability of the material is sufficient if proper procedures are followed and the right equipment is used.The strength of the welded joints can be increased by postweld heat treatment.

The bearings are made of a ceramic material known as Coors AD90 Alunima.The AD90 is a fine grained material which gives high performance and high strength in the most demanding wear resistant applications.The material also withstands inpact,erosion,and temperature with little degradation,which is important under the operating conditions.

Operating Features

The hitch is a kinematic four bar linkage designed to countour follow.The linkage was designed to give an horizontal rotational range of plus or minus forty-five degrees without interfering with the tractor.The hitch will continue to contour follow in the range plus or minus fifteen degrees change in the line of action through the rear axle.An hydraulic cylinder is used to give the hitch lifting capability of up to fifty degrees vertical.An hydraulic cylinder is also utilized in the upper linkages of the four bar,giving the hitch an adjustable pitch angle.A dual hydraulic actuator is used at the end of the hitch to give it automatic hitching capabilities.

Kinematic Hitch Hydraulic System

The kinematic hitch hydraulic system is designed to provide a complete range of movement as well as power to the hitch. The system contains five hydraulic cylinders, a set of directional control valves, a receiver, an amplifier, a transmitter, and a control board.

The five cylinders are the lift cylinder, the two link cylinders, the rotational cylinder, and the pinning cylinder.In order to provide sufficient power to lift the implement and to insure a slow enough piston velocity, the lift cylinder is 3 inch bore, 11 inch stroke. The stoke was choosen on the basis of the degree of movement required in the hitch.

The link cylinders are one of the links in the four bar linkage. They are sized according to the design force requirements, the needed link strength, and the link size requirements. They are two inch bore and twelve inch stoke. These two cyllinders are mounted pinned on both ends.

The rotational cylinder provides the necessary force to turn the implement and is used to lock the implement directly behind the tractor while transversing the face of a hill or before lifting the implement. To provide the proper range of motion for the cylinder, a head end trunnion mount was choosen. The cylinder is of the tie rod type; it has a two inch bore and a twelve inch stroke.

A special design was required to meet the size requirements of the pinning cylinder. It is a a double rod,

double acting cylinder. Each half of the cylinder has a one inch stroke and a two and a half inch bore. The rods are inch and a half diameter to handle the high shear load.

The control valve system consists of six solenoid actuated valves and two flow control valves. There are four, four way, three position directional control valves. They control the movement in the cylinders. There are two three way, two position control valves which allow the lift and rotation cylinders move freely if desired (float). Two flow control valves are also found in the system. One of these is to reduce the flow to the system from twenty-five to eight GPM. The second flow control valve limits the flow to the pinning cylinder to 2 GPM.

The electronic controls consists of a control panel, a transmitter, a receiver, and an amplifier. The control panel is simply a panel with four spring centered switches and three push button switches mounted on it. The spring centered switches each control one of the cylinder groups. The push button switches control the float capacity. The transmitter is of the type used in remote control of models; it will need to be modified to accommidate the control panel described above The reciever is also of the type used with models because of is size and weight. The amplifier is require to raise the low voltage output of the reciever to twenty-four volts DC needed in the solenoid valves. The receiver and the valves are all mounted in a single unit for convenience and ease of handling.

Rough radiant heat transfer calculations lead one to

believe that it is possible to operate within an acceptable temperature range without a temperature control system. It recommended that the exposed cylinders be painted with a Lithium-Aluminum silicate paint. It is also recommended that a finite element heat transfer analysis be under taken with better lunar surface irradience data if possible. It will be necessary to prewarm the hydaulic sytem before start-up if the hitch is unuse for a long period during the night. This may be done be covering the hitch and control box with an electrical resistive blanket coated an the out side with a reflective material. This is necessary becuase of the change in viscocity due to heat lost to the soil.

D. Cost Analysis

Production Costs and Transportation Considerations

The total cost of producing and transporting any device involves many considerations:material costs, manufacturing costs including labor,and quantity for production.In designing for space applications ,a chief consideration is transportation costs.The product must be lightweight without sacraficing strength and rigidity.There must be a high insurance against failure,since repairs are virtually impossible.Money saved in production would become money waisted in the event of failure while in use.

Most of the Kinematic hitch is made from an aluminum alloy.Although aluminum tends to be more expensive then steel,the higher weight to strength ratio is imperative.It is estimated that each pound reduction in weight for a space vehicle ,can result in a savings of $30,000 or more.Reduction in weight leads to reduction in fuel costs,launch costs,and increased speed.An additional way to reduce weight is to utilize parts with thin cross sections.This also means less material costs will be incurred,however thinner cross sections can lead to manufacturing difficulties .An advantage of aluminum is its ease in manufacturability.

Another way of reducing costs is by using standardized parts.the ceramic bearings,hydraulic cylinders,and the control box used in the hitch are all readily available from other manufactures.Parts that had to be designed were given fairly wide tolerances,simple geometries and did not specify polished surface finishes.

In general,small production quantites lead to higher costs since more direct labor is involved and since any tooling costs are distributed over many parts.A balance must be made between decreasing prodution costs producing sound prices.Both considerations are important,but when a choice between the two exists,quality takes precendance over cost savings.

E. Hazard Analysis

Failure Modes and Consequences

The lunar Kinematic hitch has been designed for a variety of operational modes,both normal operating and upset modes.A summary of these modes can be found in the stress analysis section of the appendix.Statically determined analysis of normal operational modes for various angles of contour follow was performed by computer.A computer output along with the program listing and a sample calculation is included in the stress analysis.In statically indeterminant loading,the hitch components have been conservatively modeled as simple beams or analyzed using energy techniques.The material properties are taken at seventy degrees fahrenheit.Actual temperature will vary greatly, but since Alunimun 2218 has high strength at elevated temperatures,and,in general its strength and ductility remain the same or improved at lower temperatures,analysis at seventy degrees fahrenheit is acceptable.Welds and the tongues for the pins joints are considered the weak point of structure.

The hitch was designed to a drawbar pull of 4000 pounds.The maximum weight of the implements to be used was estimated at 1000 pounds.Normal dragging forces were considered as well as the forces due to an unrestricted lifted flopping over,the torsion encountered by hitting a rock,and the forces involved when the implement dropped into the ground after the tractor has reached a speed of 6 mph.Normal conditions include side hill slopes of fifteen degrees and turns which cause a implement angle of up to forty degrees with the tractor centerline.When the tractor attempts a turning radius smaller than this,a torsion capable of sliding the tractor is considered.Where loading conditions can be combined,direct superposition is enployed.

The difficulty in performing a failure analysis for this hitch is that its' highest priority is that it not foil.The loading conditions and stress analysis are very conservative,since repair facilities on the moon will be negliable.Under the postulated conditions the hitch will not foil,including certain user abusive loading conditions such as tool flop.Of course there are always conditions which are unforeseen and the hitch should by no means be considered indestuctable by the operator.Though the stress analysis is considered conservative,it is very crude.A detailed stress analysis using finite element techniques should be performed before final design.

F. Operating Instructions

Disassembly

1)Remove cotter pins from hydraulic cylinder links

2)Remove axle pins

3)Tap hydraulic cylinder loose and lay down

4)Replace cotter pins in axle pins

5)Remove cotter pins from lower links

6)Remove axle pins

7)Replace cotter pins in axle pins

8)Tap out lower links

* Assembly is above procedure in reverse.

Implement Changing Procedure

1)Disengage dual piston hydraulic actuator

2)Removal of the implement may be achieved thru one of the following methods:

A)Physically grasp and pull implement off of tounge

B)Move tractor forward until implement is disengaged .If implement does not slide off easily ,hold implement while tractor moves forward.

3)Replacing removed implment requires line-of-sight adjustment for new implement.New implement should be in line with tongue prior to attachment.

4)Tractor should be backed onto the implement.Full attachment results when implement backsup with tongue.

5)After full engagement,stop tractor,rengage dual piston actuator.When pins are visible ,implement is ready.

Instructions for Operating the Kinematic Hitch

The kinematic hitch is hydraulicly powered. There are five cylinders in the hitch. The first of these cylinders is designed primarily for lifting the implement out of the gound. The lift cylinder can, however, be used to force the implement into the gound by using the weight of the tractor. This will result in the lost of traction in the tractor. The next two cylinders operate as a pair. These are refer to as the linkage cylinders. Their main function is to allow the operator to change the pitch of the implement. The use of this feature will require some experience to master. The primary idea is that by extending the cylinders the operator can lessen the pitch of the tool. Conversely, by retracting the cylinders the operator can increase the pitch of the implement. By extending and retracting these cylinders the operator can maintain a constant cutting depth in varying soil conditons. The fourth cylinder is refered to as the rotational cylinder. It function is rotate the implement relative to the hitch. Two most common uses for this cylinder are to center the implement behind the tractor before lifting it to full height so as not to tip the tractor over and to hold the implement behind the tractor while transversing the side of a hill. The final cylinder is the pinning cylinder. Its purpose is to allow fully remote changing of inplements. While retracted in inplement can be slid over the tongue; when extended the pins should fit through the holes in the top and bottom of the implement

sleeve.

The actual operation of the hitch is very simple. It is designed to be purely remote controlled. WARNING!!! Since the hitch is purely remote conrolled it HIGHLY recommended that the tractor be conpletely shut down before approaching it. The hitch is controlled with six switches, four, three position and two, two position switch. All of the three postion switches control the directional movement of a particular cylinder (i.e. extention or retraction). The center postion locks cylinder in it present postion. Floating (allowing free movment of the cylinder) the lift and rotational cylinders can be accomplished using the two postion switches. Under normal circumstances both cylinders are floated once the implement is on the ground. Extreme care should be taken not to float either cylinder while the implement is elevated. This could cause serious damage to hitch and the tractor. It could also lead to serious or fatal injury to the operator. There is a float control safty switch on the control panel to accidental floating of the lift or rotational cylinders. In order to float either cylinder it is necessary to depress both the float safty switch and the proper float control switch simulaneously in order to float the cylinders.

Directional control of the cylinders is simply accomplished by moving the sping centered control switch of the desired cylinder in the desired direction. To extened the cylinder push the switch forward; to retract it pull the switch backward. When the switch is released the cylinder

is locked in place.

REMEMBER!!!! Never approach the tractor without first shutting down the power!!!! Never float the lift or rotational cylinders with the implement lifted out of the ground!!!!!

Connection of the Hydraulic Sytem

Connection of the hydraulic is very simple. It involves four easy steps. These steps are to be done after the linkage is securely in place.

STEP 1: Lift the control box into place. The box should fit over the four pins that are welded on the back horizontal surface of the tractor. Insert the cotter pins into the holes in the mounting pins.

STEP 2: Connect the supply line to the tractor. The supply line is coded with two wide bands near the end. It is connected by simply pushing the end of line onto the connector.

STEP 3: Next connect the return line. This is done in the same manner as in number two above except that the return line has no coding on it.

STEP 4: Finally, plug in the electrical connection.

G. Conclusions and Recommendations

The kinematic hitch design is compact,lightweight,durable,and accomplishes the performance goals outlined in problem statement.The greatest shortcoming of the hitch is that the hydraulic cylinders must be manipulated to control the hitch,i.e. Keep the implement from lifting or dragging into the ground,over a extensive hill or valley.Alot of research went into designs that would eliminate this problem,such as a tool bar,but alternate designs tended to compromise other design factors.Future research should explore this problem more.

APPENDIX

Position Analysis of 4-Bar

$r_1 = 6''$

$r_2 = r_4 = 28''$ $\qquad \theta_3 = -15°$

$r_3 = 9\frac{1}{8}''$

$$-r_1 + r_2\cos\theta_2 + r_3\cos\theta_3 + r_4\cos\theta_4 = 0$$
$$r_2\sin\theta_2 + r_3\sin\theta_3 + r_4\sin\theta_4 = 0$$

$$\frac{r_2^2 - r_1^2 - r_3^2 - r_4^2}{2r_3r_4} + \frac{r_1}{r_4}\cos\theta_2 + \frac{r_1}{r_3}\cos\theta_4 = \cos(\theta_3 - \theta_4)$$

or $\quad -.233 + .207 + .658\cos\theta_4 = \cos(15 - \theta_4)$

$$.658\cos\theta_4 - \cos(15 - \theta_4) = .026$$

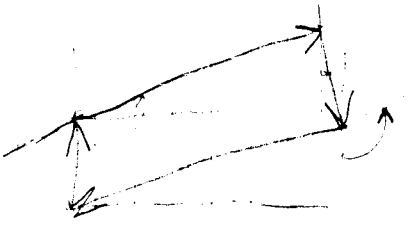
By iteration, $\theta_4 \doteq 306.3°$

$\theta_1 = 180°$

$\theta_3 = 15°$

$$\theta_2 = \cos^{-1}\left[\left(r_1 - r_3\cos\theta_3 - r_4\cos\theta_4\right)/r_2\right]$$

$= 133.8$

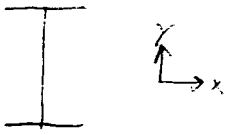


$\alpha = \theta_4 - 270, = 36.3°$

$\gamma = \theta_2 - 90, = 43.8°$

Cross-Section Properties

I-beam:



$A = (1.25+1.5)(.125) = .3438\ in^2$

$I_x = \frac{1}{12}(.125)(1.25)^3 + 2\left[\frac{1}{12}(.75)(.125)^3 + \left(\frac{1.25}{2}\right)^2(.75)(.125)\right]$

$= .0938\ in^4$

$I_y = \frac{1}{12}\left[(1.25)(.125)^3 + 2(.125)(.75)^3\right]$

$= .0090\ in^4$

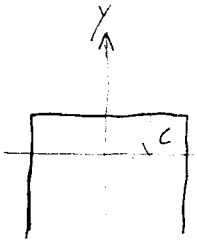
$J_e = \frac{1}{3} h b^3 \quad b = t = .125"$

$h = 2w + d - 2t$

$= 2.75"$

$= .0018\ in^4$

Channel-Beam



$A = (1.25 + 1.25 + .75)(.125)$

$= .4063\ in^2$

$.4063\,c = 2(1.25)(.125)\left(\frac{1.25}{2}\right)$

$c = .4807\ in$

$I_x = \frac{1}{12}\left[2(.125)(1.25)^3 + (.75)(.125)^3\right] + (.4807)^2(.75)(.125) + (.1443)^2(1.25)(1.25)(2)$

$= .0690\ in^4$

$I_y = \frac{1}{12}\left[2(1.25)(.125)^3 + (.125)(.75)^3\right] + (.375)^2(1.25)(.125)(2)$

$= .0487\ in^4$

$J_e = \frac{1}{3}(3.25)(.125)^3, = .0021\ in^4$

Cylinders

$I_x = I_y = \frac{\pi}{64}(d_o^4 - d_i^4)$

$= .0491\ in^4$

$J = 2I, = .0982\ in^4$

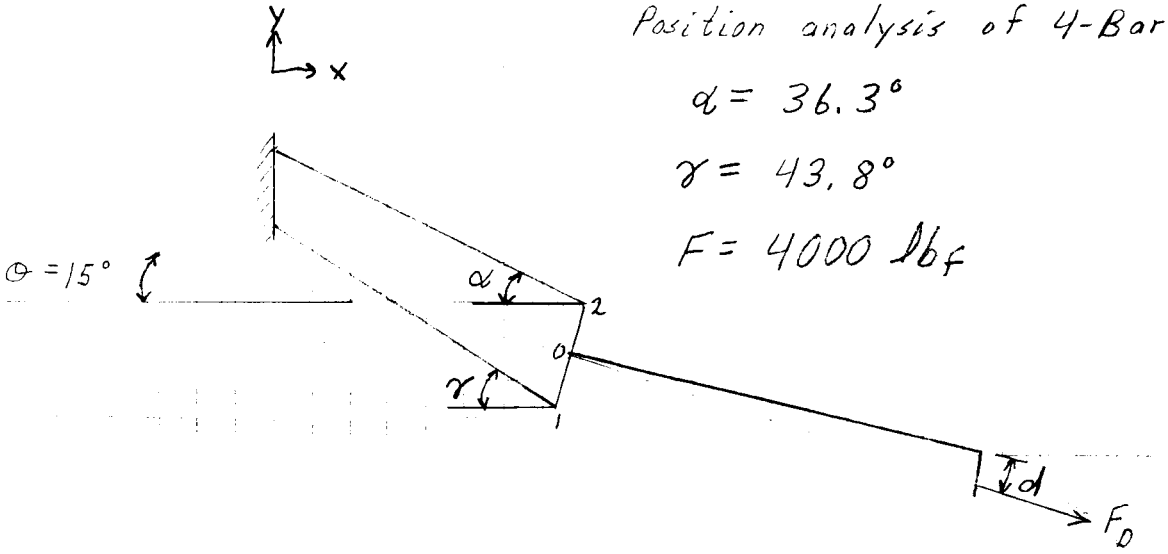
Force Analysis

Normal Operation (Flat Ground)

$$2T\left(\cos\left(\sin^{-1}\left(\frac{9\frac{1}{8}-6}{2(28)}\right)\right)\right) = 3600\ lb_f$$

$$\boxed{T = 1803\ lb_f}$$

Operation w/ Contour Follow @ 15° slope



Position analysis of 4-Bar yields:

$\alpha = 36.3°$

$\gamma = 43.8°$

$F = 4000\ lb_f$

$$\Sigma F_x = T\cos\alpha - F_D\cos\theta - R_x = 0$$

$$\Sigma F_y = T\sin\alpha - F_D\sin\theta + R_y = 0$$

$$\Sigma M_1 = \left[T\cos(\alpha-\theta)\right]r_3 - F_D\left(\frac{r_3}{2} - d\right) = 0$$

Dragging $\Rightarrow d = 0$:

$T = 2147\ lb_f$ $\quad R_x = -2134\ lb_f$ $\quad R_y = -236\ lb_f$

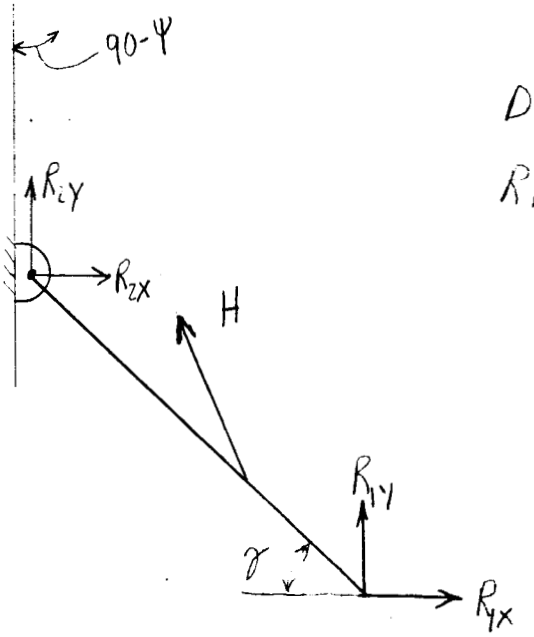
Digging $\Rightarrow d \approx 12''$

$T = -3499\ lb_f$ $\quad R_x = -6684\ lb_f$ $\quad R_y = 3107\ lb_f$

$F_A = (-6684i + 3107j)\cdot(-.722 + .692)$ $\quad F_L = (-6684i + 3107j)\cdot(+.692i + .722j)$

$= 6980$ $\quad = -2380$

To Hold Down 4-Bar for Contour Follow @ $\theta = 15°$:



Digging Implement

$R_{1x} = 6684 \quad R_{1y} = -3107$

$$\sum M_2 = (l\cos\gamma)H\cos(90-\Psi) - (l\sin\gamma)H\sin(90-\Psi) + (-3107)(28)\cos\gamma + (6684)(28)\sin\gamma = 0$$

$\gamma = 43.8°$

Let $l = 18''$ & $90-\Psi = 25°$

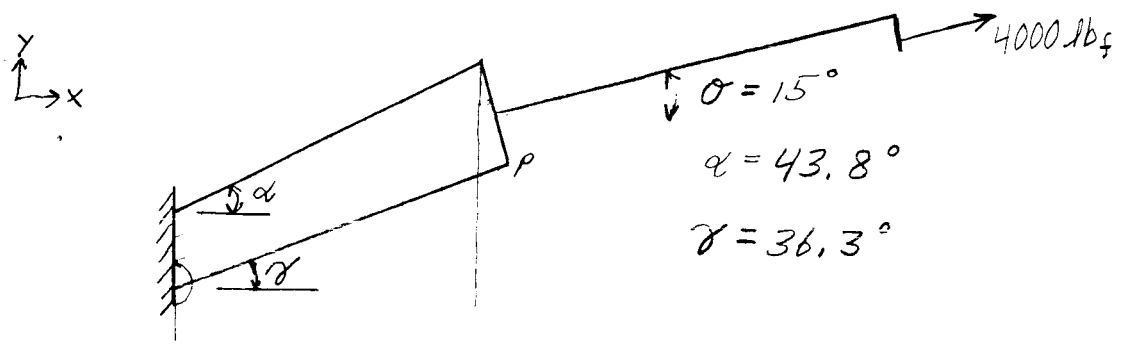
then $H = -10,254$ lbf

$$\sum F_x = R_x + F_x - H\sin(90-\Psi) = 0$$

$$R_x = -11,020$$

$$\sum F_y = R_y + F_y + H\cos(90-\Psi) = 0$$

$$R_y = 12,400$$



$$\Sigma F_x = -T\cos\alpha + F_x + 4000\cos 15^\circ = 0$$

$$\Sigma F_y = -T\sin\alpha + F_y + 4000\sin 15^\circ = 0$$

$$\Sigma M_p = \left[T\cos(\alpha - \theta)\right] r_3 - F_D\left(\frac{r_3}{2} - d\right) = 0$$

$T = -3720$ lbf $\qquad F_x = -6550 \qquad F_y = -3610$

$$F_A = (-6550i - 3610j)\cdot(-.806 - .592)$$

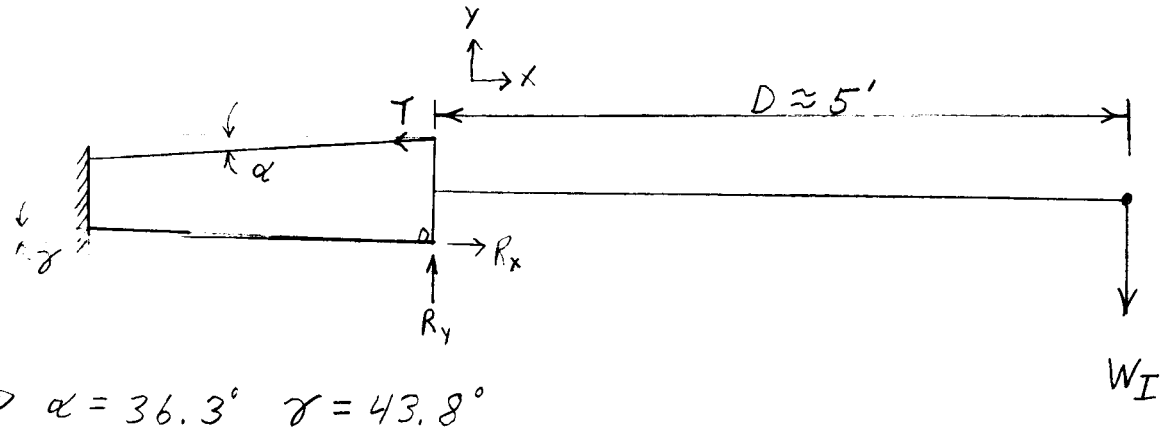
$$= 7420$$

$$F_L = (-6550i - 3610j)\cdot(-.592 + .806)$$

$$= 970$$

Forces During Lifing of Implement

$\theta = -15, 0°, 15°$



$\theta = -15° \Rightarrow \alpha = 36.3° \quad \gamma = 43.8°$

$$\sum F_x = -T\cos\alpha + R_x = 0$$

$$\sum F_y = T\sin\alpha + R_y - W_I = 0$$

$$\sum M_0 = T\cos\alpha(r_3\cos\theta) + T\sin\alpha(r_3\sin\theta) - W_I[D\cos\theta + (r_3/2)\sin\theta]$$

Assume $W_I \approx 500\ lb_f$

$T = 3478\ lb_f \quad R_x = 2803\ lb_f \quad R_y = -1559\ lb_f$

$\theta = 0° \Rightarrow \alpha = -3.2° \quad \gamma = 3.2°$

$T = 3293\ lb_f \quad R_x = 3288\ lb_f \quad R_y = 316\ lb_f$

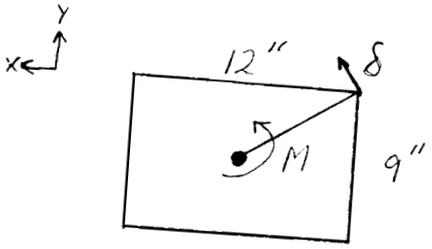
$\theta = 15° \Rightarrow \alpha = -43.8 \quad \gamma = -36.3$

$T = 3550\ lb_f \quad R_x = 2562\ lb_f \quad R_y = 2957\ lb_f$

Tool Flop Analysis

Assumptions:
1) Weight of implement is 100 lbm (conservative)
2) CG of implement is 5 ft from hitch
3) Hitch is lifted up to $\theta_3 = 15°$.

$$U_t = \frac{1}{2}\frac{T^2 L}{GJ} \qquad U_b = \frac{2F^2 L^3}{3EI} \qquad U_c = \frac{1}{2}\frac{P^2 L}{AE}$$

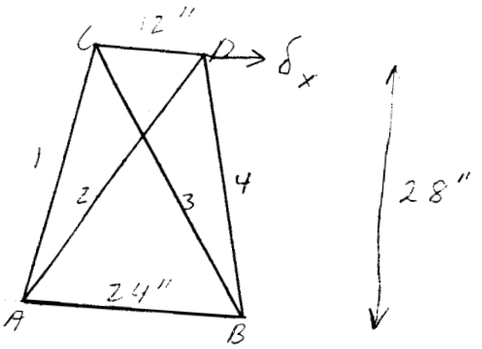


$$\delta_x = 7.5(\sin 41.4)\theta$$
$$= 4.96\theta \text{ (in inches, for small } \theta)$$

$$F = \left(\frac{3EI}{L^3}\right)\delta_F$$

$$P = \left(\frac{EA}{L}\right)\delta_P$$

$$T = \left(\frac{GJ}{4.96L}\right)\delta_T$$



If we assume pin joints @ C & D and uncouple the intersection of the cross brace, we have 6 beams.

For beams 1 & 4 $\delta_F = \left(\frac{28}{28.6}\right)\delta_x$ $\delta_P = \left(\frac{6}{28.6}\right)\delta_x$ $\delta_T = \delta_F$

For beams 2 & 3 $\delta_F = \left(\frac{28}{33.3}\right)\delta_x$ $\delta_P = \left(\frac{18}{33.3}\right)\delta_x$ $\delta_T = \delta_F$

$$F_{1,4} = \left(\frac{3EI}{L^3}\right)\left(\frac{28}{28.6}\right)\delta_x = 12.19\,\delta_x$$

$$P_{1,4} = \left(\frac{EA}{L}\right)\left(\frac{6}{28.6}\right)\delta_x = 27{,}236\,\delta_x$$

$$T_{1,4} = \left(\frac{GJ}{4.96L}\right)\left(\frac{28}{28.6}\right)\delta_x = 47.69\,\delta_x$$

$A = .3438, .4063 \text{ in}^2$
$G = 3.86\times10^6$ psi
$E = 10.8\times10^6$ psi
$J_e = .00179 \text{ in}^4$ (non-circular cs appx.)
$I = .00899 \text{ in}^4$
$L = 28.6, 33.3$ in

$$F_{2,3} = \left(\frac{3EI}{L^3}\right)\left(\frac{28}{33.3}\right)\delta_x = 36.26\,\delta_x$$

$$P_{2,3} = \left(\frac{EA}{L}\right)\left(\frac{18}{33.3}\right)\delta_x = 71{,}229\,\delta_x$$

$$T_{2,3} = \left(\frac{GJ}{4.96L}\right)\left(\frac{28}{33.3}\right)\delta_x = 41.27\,\delta_x$$

$A = .4063 \text{ in}^2$
$J_e = .0021 \text{ in}^4$
$I = .0487 \text{ in}^4$
$L = 33.3$ in.

For top hydraulics there is only bending, torsion

$F_c = \left(\frac{3EI}{L^3}\right)\delta_x = 201.3\,\delta_x$ $\quad T_c = \left(\frac{GJ}{1.76L}\right)\delta_x = 8485\,\delta_x$

$E \sim 30\times10^6$ psi
$L = 28''$
$I = .0491$ in.^{4}

$G \sim 12\times10^6$ psi
$J = .0982$ in.^{4}

$\Delta PE = U = U_t + U_b + U_c$ Solve in terms of $F_{1,4}$

$\Delta PE = (1-\sin 45°)(\sin 15°)(5\text{ ft})\left(\frac{1000\text{ ft-lbs}}{6\text{ ft-lbs/lbf}}\right)$

$= 758$ in-lbf

$$758 = 2\left[\left(\frac{2(F^2)(28.6)^3}{3(10.8\times10^6)(.0090)}\right)+\left(\frac{1}{2}\frac{(2234F)^2(28.6)}{(.3438)(10.8\times10^6)}\right)+\left(\frac{1}{2}\frac{(3.91F)^2(28.6)}{(3.24\times10^6)(.0018)}\right)\right]$$

$$+2\left[\left(\frac{2(2.47F)^2(33.3)^3}{3(10.8\times10^6)(.0487)}\right)+\left(\frac{1}{2}\frac{(5843F)^2(33.3)}{(.4013)(10.8\times10^6)}\right)+\left(\frac{1}{2}\frac{(3.25F)^2(33.3)}{(3.24\times10^6)(.0021)}\right)\right]$$

$$+2\left[\frac{2(16.5F)^2(28)^3}{3(30\times10^6)(.0491)}+\left(\frac{1}{2}\frac{(696F)^2(28)}{(12\times10^6)(.0982)}\right)\right]$$

$F_{1,4} = 1.652$ lbf (ie must of energy goes into compression or tension of members, not bending or torsion.)

$F_{2,3} = 4.9$ lbf

$P_{1,4} = 3690$ lbf

$P_{2,3} = 9650$ lbf

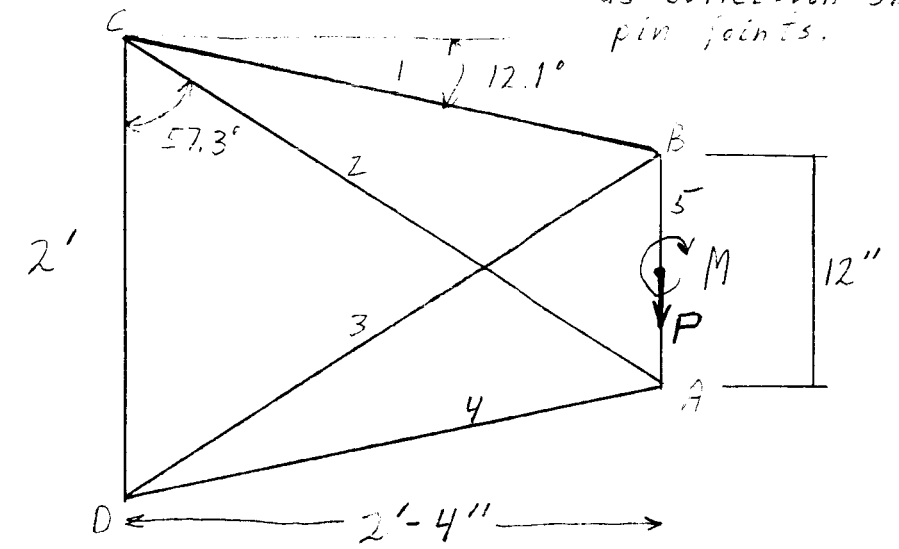
$T_{1,4} = 6.5$ in-lbf

$T_{2,3} = 6.4$ in-lbf

$F_c = 27$ lbf

$T_c = 1150$ in-lbf

Turning Force Analysis; Structure is modeled as collection simple members w/ pin joints.



$$\sum M_C = 28P + M - 24D_x$$

$$D_x = -C_x = \frac{28P + M}{24}$$

$$C_y = P - D_y$$

This problem is statically indeterminant of order 1, D_y is considered an applied force.

In link 5

$$\sum M_A = 12(.9778F_1 + .8415F_3) - M_5 = 0$$

$$\sum F_x = .9778(F_1 + F_4) + .8415(F_2 + F_3) = 0$$

$$\sum F_y = .2096(F_1 - F_4) + .5402(F_2 - F_3) - P = 0$$

Node Eq.s $\quad .9778F_1 + .8415F_2 + C_x = 0 \Rightarrow .9778F_1 + .8415F_2 = \frac{22P + M}{24}$

$$-.8415(.2096F_1 + .5402F_2 = P - D_y)$$

$$.8014F_1 = .3252P + .0351M - .8415D_y$$

$$\boxed{F_1 = .4058P + .0438M - 1.0500D_y}$$

$$.2096(.4058P + .0438M - 1.0500D_y) + .5402F_2 = P - D_y$$

$$\boxed{F_2 = 1.6937P - .0092M - .7810D_y}$$

$$.9778F_4 + .8415F_3 = \frac{-28P - M}{24}$$

$$-.8415\left(.2096F_4 + .5402F_3 = -D_y\right)$$

$$.2014F_4 = -1.1667P - .0417M + .8415D_y$$

$$\boxed{F_4 = -1.4558P - .0520M + 1.05D_y}$$

$$.2096(-1.4558P - .0520M + 1.0500D_y) + .5402F_3 = -D_y$$

$$.5402F_3 = .3051P + .0109M - 1.2201D_y$$

$$\boxed{F_3 = .5648P + .0202M - 2.2586D_y}$$

Tension in link 5:

$$F_5 = .2096F_1 - .5402F_3$$

$$\boxed{= -.2369P - .0017M + D_y}$$

$$U = \sum \frac{1}{2}\left(\frac{F^2L}{AE}\right)$$

$$(\delta_D)_y = \frac{\partial U}{\partial D_y} = \sum \frac{FL}{AE}\frac{\partial F}{\partial D_y} = 0$$

$$\frac{L}{AE}\left[(.4058P + .0438M - 1.0500D_y)(1.0500) + (-1.4558P - .0520M + 1.0500D_y)(1.0500)\right]$$

$$+ \frac{L}{AE}\left[(1.6937P - .0092M - .7810D_y)(-.7810) + (.5648P + .0202M - 2.2586D_y)(-2.2586)\right]$$

$$+ \frac{L}{AE}\left(-.2369P - .0017M + D_y\right) = 0$$

· Links	1 & 4	$L = 28.6''$	$A = .3438\ in^2$	$E = 10.8 \times 10^6\ psi$
· Links	2 & 3	$L = 33.3''$	$A = .4063\ in^2$	$E =$ " "
Link	5	$L = 12''$	$A = 3.75\ in^2$	$E =$ " "

$$\frac{(28.6)}{(.3438)(10.8\times10^6)}\left(-1.9547P - .1006M + 2.2050D_y\right)$$

$$+ \frac{(33.3)}{(.4063)(10.8\times10^6)}\left(-2.5984P - .0384M + 5.7112\,D_y\right)$$

$$+ \frac{(12)}{(3.75)(10.8\times10^6)}\left(-.2369P - .0017M + D_y\right) = 0$$

(↑ negl.)

$$-375.6P - 11.5M + 651.5D_y = 0$$

$$\boxed{D_y = .5765P + .0177M}$$

Turning:

$P = .7071\,(4000), = 2828\ lb_f$ $\quad M = negl.$

$D_y = 1630\ lb_f$ $\quad C_y = 1198$

$D_x = 3300$ $\quad C_x = -3300$

Over turning to slide:

$P = 2828\ lb_f$ $\quad$ (Assume $\mu_s = 0.5$)

$$M = \frac{14261\ lb_m}{(2)6\ lb_m/lb_f}\,(7.67\ ft), = 9115\ ft\cdot lb_f$$

$$= 109{,}400\ in\cdot lb_f$$

$D_y = 3567\ lb_f$ $\quad C_y = -739$

$D_x = 7858$ $\quad C_x = -7858$

Deflection

$$(\delta_A)_y = \frac{\partial U}{\partial P} = \sum \frac{FL}{AE}\frac{\partial F}{\partial P}$$

$$\frac{28.6}{(1.3438)}\left[(.4058P + .0438M - 1.0500D_y)(.4058) + (-1.4588P - 0.520M + 1.05D_y)(-1.458)\right.$$

$$+ \frac{33.3}{(.4063)}\left[(1.6937P - .0092M - .7810D_y)(1.6937) + (.5648P + .0202M - 2.2586D_y)(.5648)\right.$$

$$= \delta\,(10.8 \times 10^6)$$

$\delta = .0613"$ (turning)

$\delta = .0694"$ (overturn to slide)

Forces

Turning

$F_1 = -565\ lb_f$

$F_2 = 3516\ lb_f$

$F_3 = -2085\ lb_f$

$F_4 = -2406\ lb_f$

Over Turning to Slide

$F_1 = 2194\ lb_f$

$F_2 = 998\ lb_f$

$F_3 = -4250\ lb_f$

$F_4 = -6060\ lb_f$

Note that this analysis is conservative because the model assumes pinned connections, giving the structure more flexibility than is actually present.

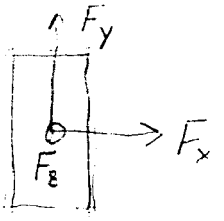
Stress Check

The weak point in the structure is the mounting bracket. As the force analysis shows, there is very little bending and all cross sections are strong enough to handle the loads.

Maximum load = 6000 lbf
Small cross sectional area = .3438 in²

$\sigma_{max} = 17,452 < S_y = 46,000$ psi

On the mounting bracket:



Max. load $F_x = 3567$ lbf
$F_y = 6200$ lbf
$F_z = 6200$ lbf

.25" fillet weld all the way around

$$S_s = \frac{P}{(0.707)hL} = \frac{\sqrt{(3567)^2 + (6200)^2 + (6200)^2}}{(0.707)(.25)(7)} \doteq 7650 \text{ psi} < S_y$$

Taking into account moments:

About y-axis

$S_T = Kr \qquad T = \int S_T r\,dA$

$= K \int r^2\,dA$

$S_T = \frac{Tr}{J}$ where $J = \int r^2\,dA$

$\doteq (.5)^2(.25)(5)$

$= .3125 \text{ in.}^4$

$$S_T = \frac{6200(0.5)}{.3125}$$

$= 9920 \text{ psi} < S_y$

Shear strength of pins

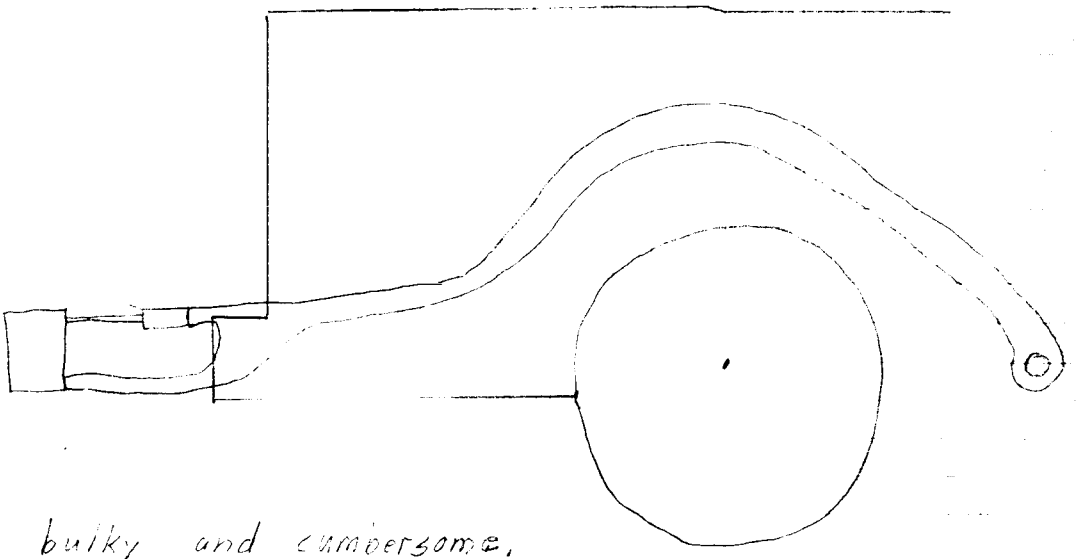
$$P = [2(6200^2)]^{1/2}, = 8770 \text{ lbf}$$

$$A = \pi r^2, = \pi (.3125)^2, = .307 \text{ in}^2$$

$$\sigma = \frac{P}{A}, = \frac{8770}{.307}, = 28,600 \text{ psi} < S_y$$

Alternative Designs

1) Tool-Bar Configuration



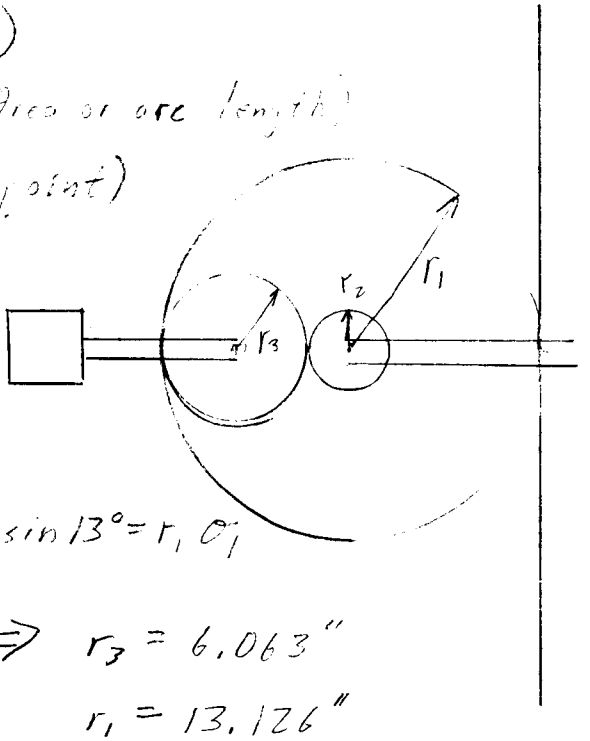
Considered too bulky and cumbersome.

2) Geared Design

$\theta_1 = \theta_2$ (rotation)

$S_2 = S_3$ (Surface Area or arc length)

$\theta_3 = 13°$ (precision point)



$r_1 = r_2 + 2r_3$

$S_1 = (54 + r_1 + r_2 + r_3)\sin 13° = r_1 \theta_1$

Setting $r_2 = 1'' \Rightarrow r_3 = 6.063''$

$r_1 = 13.126''$

This design was considered to bulky and complicated with low durability.

HYDRAULIC DESIGN CALCULATION

Pinning Cylinder sizing

shaft failure in shear for design use a moderate strength Al alloy S_y = [illegible] psi
distortion energy theory
S_{sy} = [illegible] S_y
f_s = [illegible]
[illegible] psi

Assume a 7000 lb Maximun combined loading
$S_{sy} = \frac{F}{A}$
$17310.0 = \frac{7000}{\frac{\pi d^2}{4}}$
$d = 1.77$ in $A_r = 2.46$ in^2

Force required to with draw the pin
$F = F_N \mu$, Assume a moderate [illegible] surface $\mu = 0.8$
For full draw bar F_N = [illegible]
$F = 9000(0.8) = 7200$ lb

Piston size
$F_r = h_1 - A_2 \{ P - \Delta P_1 \frac{A_1 - A_2}{A_1} + \frac{A_2}{A_2} \} \frac{1}{1.05}$
$A_1 = 3.74$ in^2
$A_1 = \frac{\pi d^2}{4}$ $d = 2.18$ choose 2.5 in bore

cylinder walls
$S = \frac{PD}{D - 2.5}$ $D = 2.75$ $t = 0.25$ in

Ends $t = 3/8$ in

2 Link Cylinder Sizing

Neutral length 2'4' $S_y = 46000$ psi
Design Load 3500 psi
Cylinder in pure tension
n = 1.5 for loading

shaft ⇒ 52501b

$$52501b = 46000(A)$$
$$.1141 = A$$
$$.1141 = \frac{\pi d^2}{4}$$
$$d = .3812 \text{ in}$$

buckling

$$\frac{P}{A} = \frac{4.935 E (R_1^2 + R_2^2)}{L^2}$$
$$= \frac{4.935(30\times10^6)(.5^2 + .25^2)}{18^2} = 142795 \text{ psi}$$

rod D_o = 1in D_{in} = 0.5"

Force P_2 back pressure
$A_2 = 0.785$

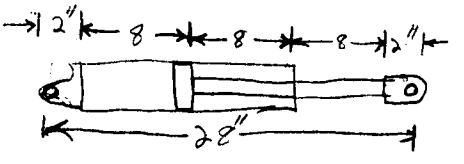
$$F_r = (A_1 - A_2)\left\{P - \Delta P\left(\frac{A_1 - A_2}{A_1} + \frac{A_1}{A_1 - A_2}\right)\right\}\frac{1}{1.05}$$

2" bore gives 4226.9 lbs retracting force
5479lb extension force

Wall thickness

$$S = \frac{PD}{2t} = \frac{2500(2.87)}{2.375} = 9566 \text{ psi}$$

Wall thickness = 3/8"

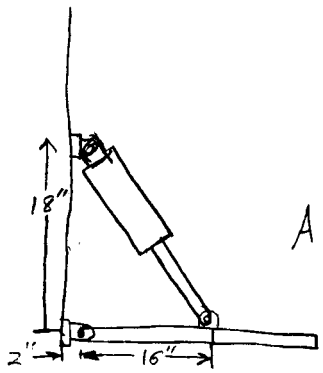


over length 28"

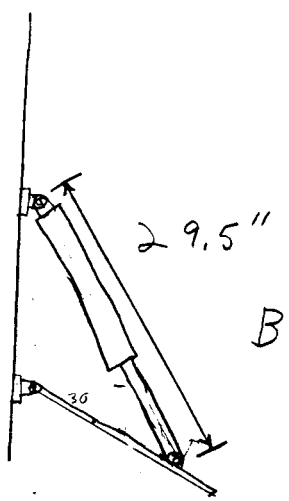
Time
full stroke 1.94 sec
Stroke 16"

Lift Cylinder Sizing

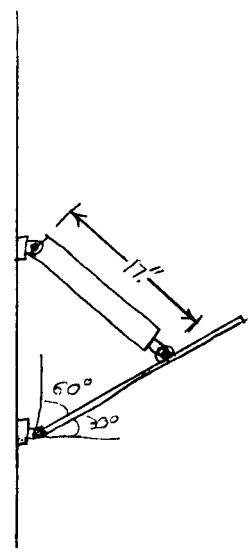
horizontal length 24.1"



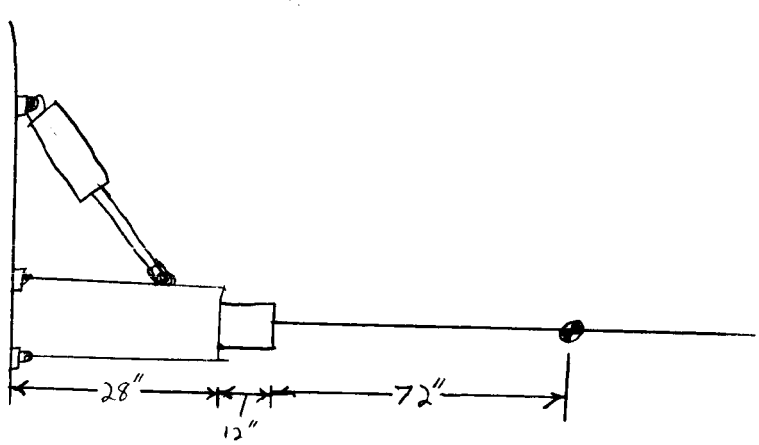
A



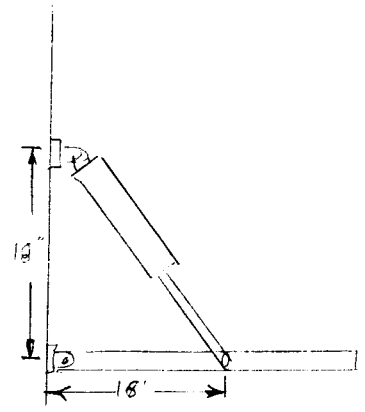
B



C



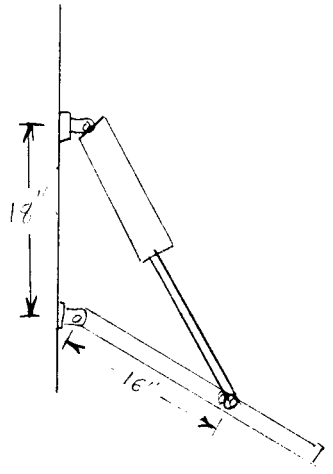
The critical case is B



horizontal length: 24.1"

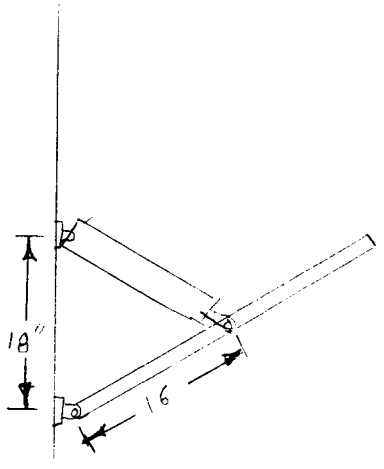
$18^2 + 16^2 = l^2$

$l = 24.1"$



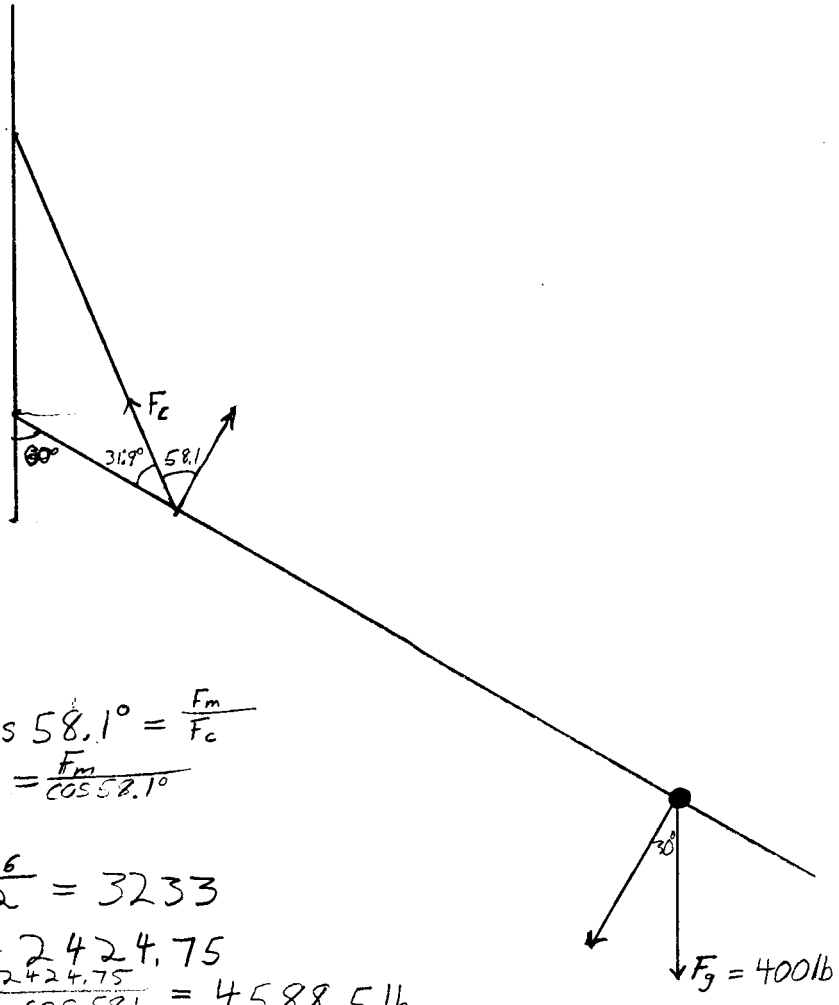
$a^2 = 16^2 + 18^2 - 2(16)(18)\cos 120°$

$a = 29.5"$



$a^2 = 16^2 + 18^2 - 2(16)(18)\cos 60$

$a = 17"$



$\cos 58.1° = \frac{F_m}{F_c}$

$F_c = \frac{F_m}{\cos 58.1°}$

$F_m \frac{16}{12} = 3233$

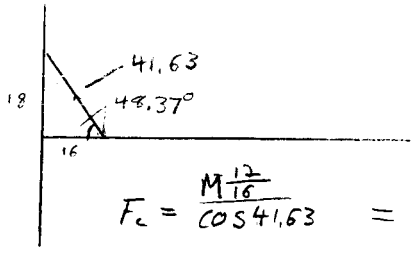
$F_m = 2424.75$

$F_c = \frac{2424.75}{\cos 58.1} = 4588.5lb$

$F_{mg} = 400 \cos 30 = 346.4lb$

$M_g = 112 \cdot 346 \frac{1}{12} = 3233\ ft \cdot lb$

Horizontal



$M_g = 400 \cdot 112 \frac{1}{12} = 3733\ ft \cdot lb$

$F_c = \frac{M \frac{12}{16}}{\cos 41.63} = 3745.7lb$

rod size
$S_y = 46000$ psi
Design load 5000 lb

tension load 5000 lb
compression load: float neglegable, locked down
$\frac{3}{4}(6000) = 4000$ 3/4 the weight of the tractor

buckling
$S = \frac{4.935 E R^2}{L^2}$ $\quad S = \frac{4.935 E (R_1^2 + R_2^2)}{L^2}$

$\sqrt{\frac{SL^2 4}{E\ 4.935}} = D = \sqrt{\frac{23000\ 16^2\ 4}{30\times10^6\ 4.935}} = D = 0.399''$ $\quad A = 0.125$

tension $46000 \frac{\pi d^2}{4} = 5000$ $\quad D = 0.3720''$
$A_2 = \pi(1^2 - 2.5^2) = 0.5890$
Rod $D_o = 1''$ $\quad D_{in} = 0.5''$

Time $= \frac{0.17 D^2 16''}{20.}$ $\quad \sqrt{T \frac{20}{16(0.17)}} = D$
3 in bore heavily restricked

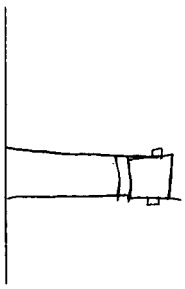
$$F_r = (A_1 - A_2)\left\{P - \Delta P\left(\frac{A_1 - A_2}{A_1} + \frac{A_1}{A_1 - A_2}\right)\right\}\frac{1}{1.05} = 5942.4 \text{ lb Min}$$

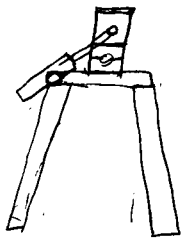
Wall thickness $\quad S = \frac{PD}{2t}$
$2S/P = \frac{D}{t} = \frac{3+2t}{t} = 3/t + 2$
$\left(\frac{2S}{P} - 2\right) = 3/t$
$t = \frac{3}{\left(\frac{2S}{P}\right) - 2} = \frac{3}{\frac{2(30000)}{2500} - 2} = .1364$ $\quad$ take $t = 0.25''$

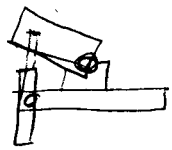
$\pi(1.75^2 - 1.5^2) = 2.55\ in^2$
$(46000) = 5000/A$ $\quad A = 0.1087$ in

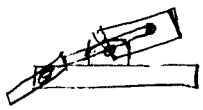
End $\quad t = 0.405 D \sqrt{P/S} = 0.405\ 3 \sqrt{\frac{2500}{3000}} = 0.3507$ in
Stroke 15" $\quad$ choose 0.5 in

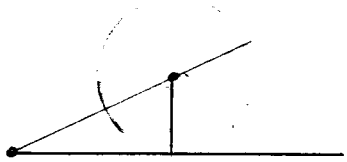
Rotational Cylinder

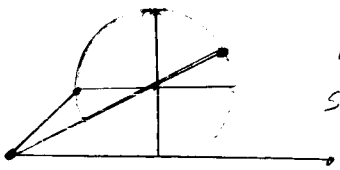




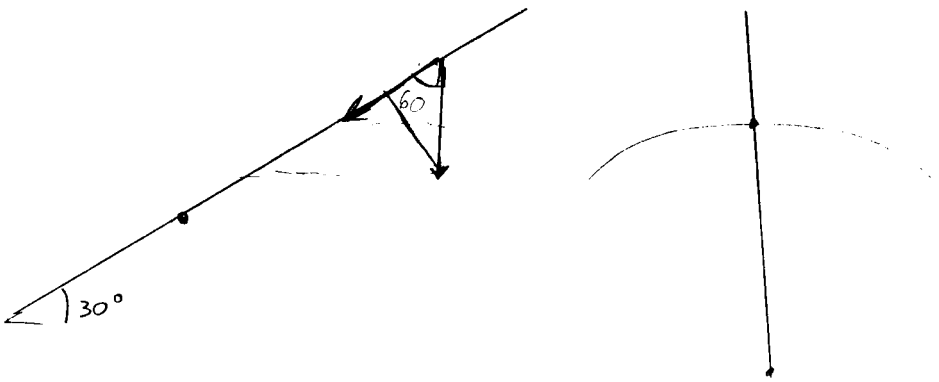








longest 12.5"
shortest 4.5"



$400\left(\frac{32.2}{8}\right)\cos 60° = 1073(5)$

$M = 5366.6 \cdot = 0.5 \times$

$10733\ lb$

$10\frac{M}{h} \quad \frac{5280}{3600} = 14.667\ ft/s$

$14.667^2\left(\frac{ft}{s}\right)(6) = 35.85\ \frac{ft}{s^2}$

$445.36\ lb(5) = 2146.667\ ft \cdot lb = F \times .5$

$F = 4293$

Design = 4500lb

Buckling

$\frac{5000}{\pi R^2} = \frac{4.935(10\times10^6)R^2}{16^2}$ $\quad R = 0.30$

D = 0.75" bore 2"

wall 0.25" Trunnion

Pipe size

$$d = \sqrt{\frac{flow}{2.04 \times Vel}}$$

$$d = \sqrt{\frac{8}{2.04 \times 10}} = 0,6262 \text{ in}$$

Alloy DIGEST

ALUMINUM 2218

DATA ON WORLD WIDE METALS AND ALLOYS

Filing Code: Al–95
Aluminum Alloy
Revised August 1978
SEPTEMBER 1960

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Upper Montclair, New Jersey

AUG 14 1978

ALUMINUM 2218

(Aluminum Forging Alloy)

ALUMINUM 2218 is an aluminum-copper-nickel-magnesium alloy (formerly designated B18S Alloy). It is a standard forging alloy and is recommended for elevated-temperature service. It is used for aircraft and jet engine components.

Composition:

	Nominal	Range
Copper	4.0	3.5-4.5
Nickel	2.0	1.7-2.3
Magnesium	1.5	1.2-1.8
Iron	–	1.0 max.
Silicon	–	0.9 max.
Zinc	–	0.25 max.
Manganese	–	0.20 max.
Chromium	–	0.10 max.
Others, each	–	0.05 max.
Others, total	–	0.15 max.
Aluminum	Remainder	Remainder

Physical Constants:

Density, lb/cu in. (At 68°F)		0.102
Specific gravity		2.81
Melting range, °F (°C)		940-1175 (504-635)
Specific heat, Btu/lb/°F		26
Thermal coef. expansion/°F (68-212°F)		12.4 x 10^{-6}
°C (20-100°C)		22.3 x 10^{-6}
Thermal conductivity,* Btu/ft^2/in./hr/°F	(At 77°F)	1070
cal/cm^2/cm/s/°C	(At 25°C)	0.37
Electrical resistivity,* Ohms-cir mil/ft	(At 68°F)	26
microhm-cm	(At 20°C)	4.3
Electrical resistivity,*† % IACS	(At 68°F)	40
Modulus of elasticity,* psi		10.8 x 10^6
MPa		74 x 10^3
Modulus of rigidity, psi		3.85 x 10^6

*T61 temper. †Equal volume.

PROPERTIES

Table 1 – TYPICAL MECHANICAL PROPERTIES – Forgings

Property	T61 Temper	T71 Temper	T72 Temper
Tensile strength, psi (MPa)	61000 (421)	47000 (324)	48000 (331)
Yield strength (0.2% offset), psi (MPa)	46000 (317)	36000 (247)	37000 (254)
Elongation (2 in.), %	12	11	11
Brinell hardness (500-kg load, 10-mm ball)	120	100	95
Shear strength, psi (MPa)	39000 (269)	–	30000 (207)
Fatigue strength (5 x 10^8 cycles), psi (MPa)	17000 (117)	–	–

Table 2 – MECHANICAL PROPERTY LIMITS – Die Forgings
(Specimen axis parallel to direction of grain flow)

Alloy and Temper	Specified Thickness in.	Tensile Strength psi (MPa), min	Yield Strength (0.2% Offset) psi (MPa), min	Elongation (2 in. or 4D), %, min	
				Coupon	Forging
2218-T61	Up thru 4	55000 (379)	40000 (276)	10	7
2218-T72	Up thru 4	38000 (262)	29000 (200)	8	5

Insert TP 483 .A4X

Table 3 – ELEVATED-TEMPERATURE TENSILE PROPERTIES
(T61 Temper)

Test Temperature °F	Time at Temperature hours	Tensile Strength psi (MPa)	Yield Strength (0.2% Offset) psi (MPa)	Elongation (4D*) %
400	10000	22000 (152)	16000 (110)	30
500	10000	10000 (69)	6000 (41)	70
600	10000	5500 (38)	3000 (21)	85

*D = Diameter of specimen.

Heat Treatment:

O-Temper (Annealing): Heat to 765-785°F, hold at temperature for 2-3 hours, cool at a rate of about 50°F per hour to 500°F, then air cool.

T61 Temper: Solution heat treat at 950°F, quench in boiling water, age 10 hours at 340°F, air cool.

T71 Temper: Solution heat treat at 950°F, quench in boiling water, age 6 hours at 450°F.

T72 Temper: Solution heat treat at 950°F, quench in air blast, age 6 hours at 460°F.

Machinability:

Aluminum 2218 has good machining characteristics in the annealed condition. Round-nose lathe tools should have a 40-50° top rake, 8-10° clearance, and a 10-20° side rake. Since most of machining is done in the heat-treated condition, lathe tools should be ground to 10-20° top rake, 10-30° side rake, and 8-10° clearance. Parting tools should have a 15-20° top rake with a 4-5° side rake. Boring tools should be of the "hook" type having a 10-20° top rake, 10-15° side rake, and sufficient clearance in excess of 8-10° to allow heel of tool to clear the work. Planer and shaper tools for roughing cuts should have a 12-15° top rake, 32-38° side rake, and 8-10° front and side clearance. Finishing tools should have 45-50° top rake, 50-60° side rake, 8-10° front clearance and little or no side clearance. Twist drills should have larger spiral angles than standard, highly polished deep flutes, narrow lands, and up to 18° lip clearance. They should operate at peripheral speeds of 500 to 600 feet per minute. Threading taps should have highly polished flutes and should be undercut; spiral fluted taps are usually better than straight fluted. The rake angles should be increased to 12-18°.

Coarse-tooth circular saws should have a 15° side clearance, 35-40° top rake, and twice the clearance used for steel, providing a positive feed is employed. The necessity of a sturdy machine and a positive feed is strongly emphasized.

Soluble oil emulsions, kerosene, and kerosene-lard oil mixtures are recommended for most machining operations; but high viscosity lubricants are recommended for tapping operations.

Workability:

The hot-working temperature range is 500-900°F, for hot forging, heat at 970°F and forge in range of 970 to 900°F down to 500°F. All cold working should be done in the annealed or solution-treated condition.

Weldability:

This alloy can be welded with proper procedure and equipment. The inert-gas consumable-electrode arc-welding process has given satisfactory results. Gas welding, brazing or soldering are not suitable for use. This alloy is more sensitive to cracking when welding than other aluminum alloys and the joint design and fixtures must be so proportioned as to put minimum strain on the joint during the cooling period. The best filler material is parent material.

The strength of welded joints is substantially improved by postweld heat treatment. Both solution and precipitation heat treatment are the same as used for the alloy without welds. Tensile strength across the welded joint of about 80% of the minimum strength of heat-treated unwelded material is obtained. The ductility across the weld is less than that of the unwelded metal.

Specification Equivalents:

AMS 4142.
Federal QQ-A-367.

General Characteristics:

Aluminum 2218 is a forging alloy containing nominally 4% copper, 2% nickel, 1.5% magnesium and remainder aluminum. It has high strength at elevated temperatures and, in general, its strength and ductility remain unchanged or improved at low temperatures. Aluminum 2218 responds to an age-hardening heat treatment for increased strength and hardness. It has good machining characteristics in the annealed condition. The alloy can be forged readily and welded with proper equipment and procedure.

Forms Available:

Forgings and forging stock.

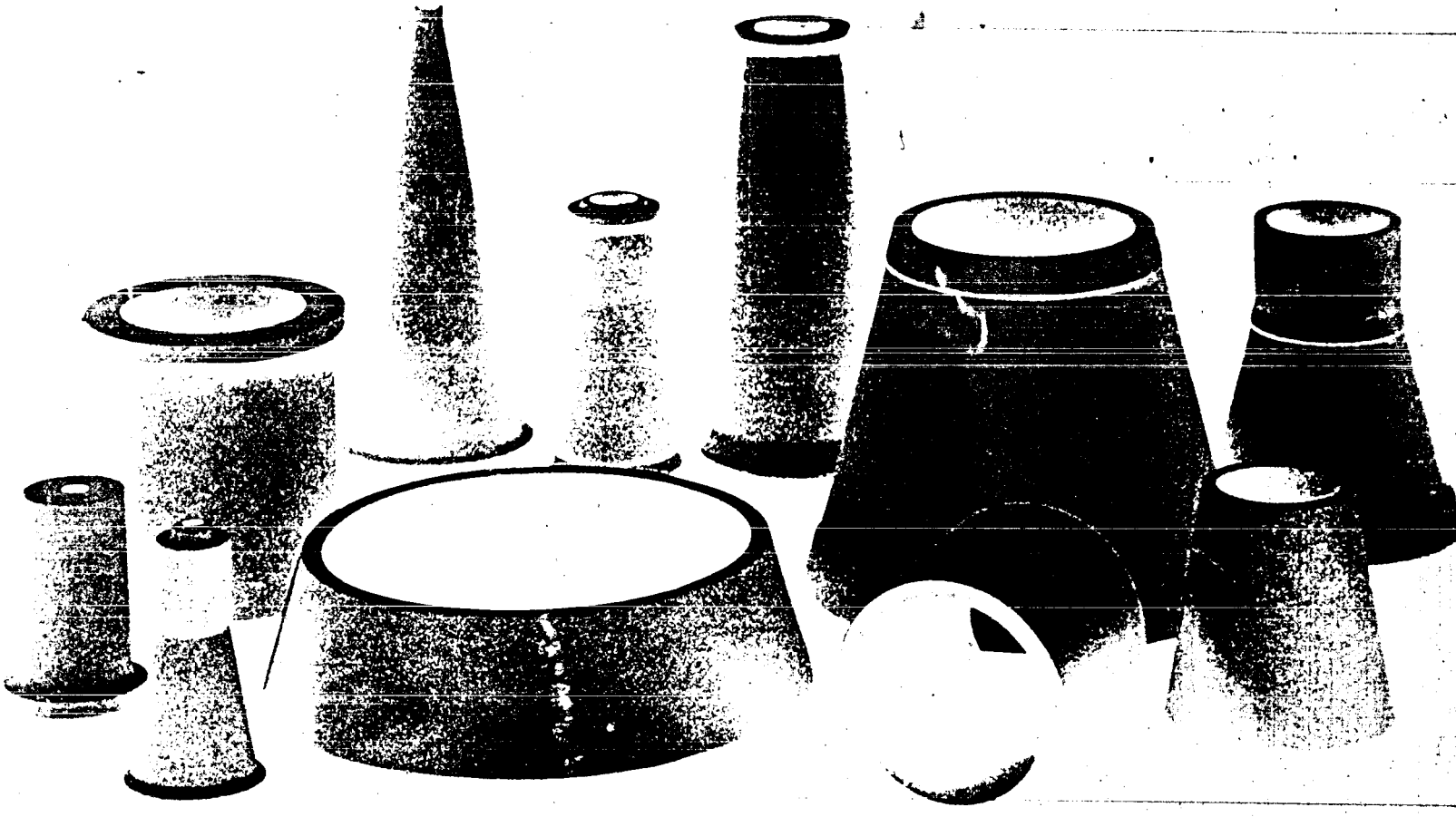
Applications:

Aircraft engine cylinders, heads and pistons. Jet engine impellers and rings.

Manufacturers:

Aluminum alloy mills.

COORS ALUMINA CERAMIC



In the tough world of coal and mineral preparation, no wear resistant surfacing material offers more than dense Coors Alumina. Hardness, impact resistance and strength make alumina the high performance choice in original equipment and replacement liners and components. Wear resistance, availability and versatility make alumina the most cost-effective lining available. It's the proven performer, time after time.

COORS ALUMINA CERAMICS WEAR LONGER.

Dense alumina ceramic has long been an industrial staple. It lasts up to 20 times longer than other specialty wear resistant materials in severe handling and processing applications. It withstands impact, abrasion, erosion and heat with little degradation. By increasing productivity and diminishing downtime, Coors Alumina cyclone liners answer industry's call for a more cost-effective materials handling solution.

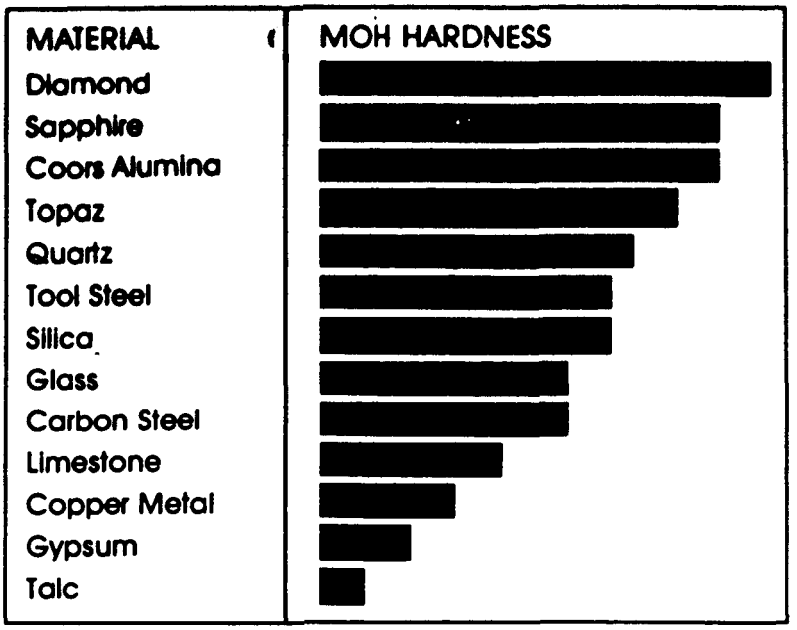
COORS ALUMINA LINERS IN THE SIZE YOU NEED.

Large, wide or tall shapes, Coors cyclone liners are readily available. You can specify Coors Alumina in any cyclone application, from 1/2 inch food process liners to 27 inch beneficiation process cones. As a major problem solver for major industry, we can design and manufacture the liner size, shape and quantity you need.

COORS ALUMINA LINERS . . . BACKED BY COORS.

When you choose Coors Alumina you get a high performance material from a high performance company. We'll help you find ways to cut costs through practical designs and conscientious customer service. We'll meet your needs for low cost, off-the-shelf replacement liners. We'll provide alumina in sensible combinations with steel and elastomer designs for easy service in the field. We'll back you with the design, material and service you need for the highest possible performance at the lowest possible cost.

HARDNESS COMPARISON



Coors AD85 Alumina is the workhorse of wear resistant industries, with a wide range of applications.

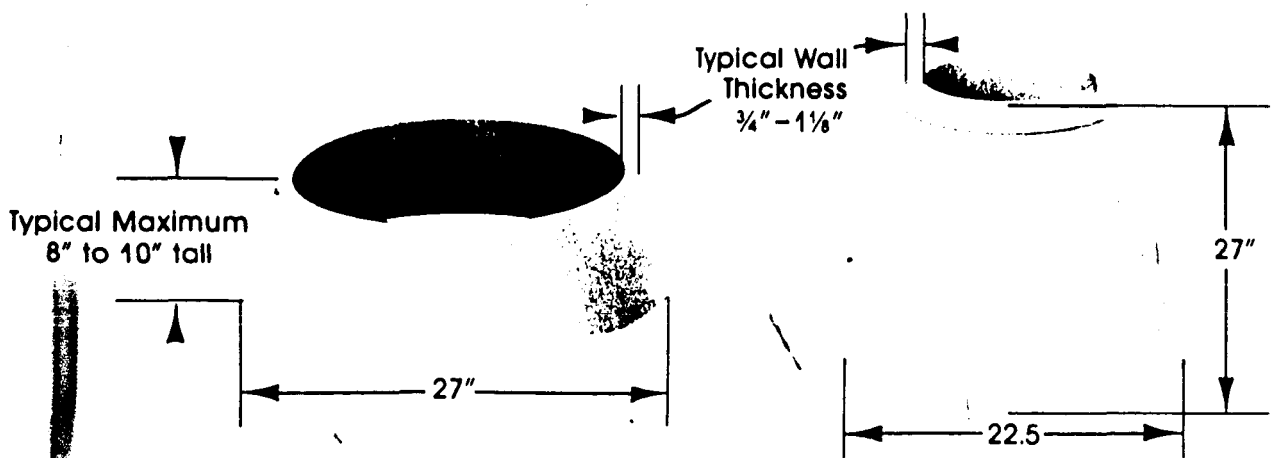
Coors AD85 is:

- Chemically resistant
- Easily fabricated
- Highly cost effective

Coors AD90 is a finer grain material for higher performance and greater strength in the most demanding wear resistant applications.

		COORS AD 85	COORS AD 90
Specific Gravity	lbs/in^3	.123	.130
Rockwell Hardness	R45N	73	79
Crystal Size Average	in x 10^{-6}	236	158
Water Absorption	ASTM C373-72	0	0
Gas Permeability	Helium test	0	0
Compressive Strength	kpsi	280	360

LARGE SHAPE CAPABILITIES



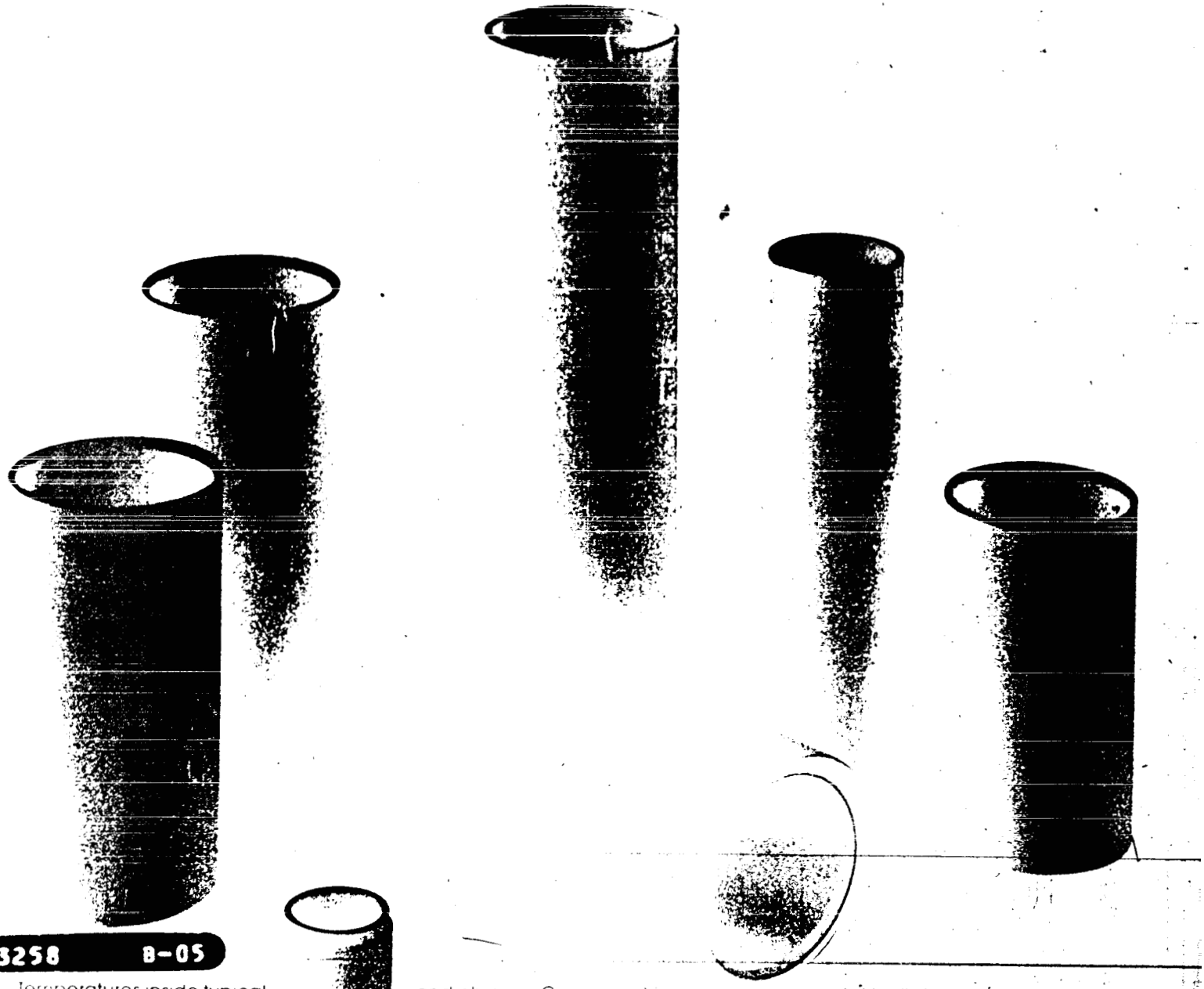
3257 B-04

Coors/CERAMICS

Coors Porcelain Company • 600 9th Street • Golden, Colorado 80401 • (303) 277-4114 • Telex #45593

Printed in USA 1/82 Bulletin No. 301

CERALINER



3258 B-05

Temperatures inside typical mud pumps can soar as high as 240 F. and pressures can top 6000PSI. Compound this punishment with the attack of harsh mud chemicals and the constant abrasion of quartz, rock and grit and you have conditions that make short work of conventional mud pump liners.

New Coors CeraLiner outwears and outlasts traditional chrome iron liners 3 to 1. It's high alumina ceramic composition offers superior performance and reduced downtime to lower your costs on pump liners and pistons.

Hardness is a good indicator of a material's ability to withstand mechanical wear and abrasion. Coors sapphire hard alumina CeraLiner is harder than any naturally occurring material except the diamond. It can take the abuse of constant abrasion long after chrome has failed.

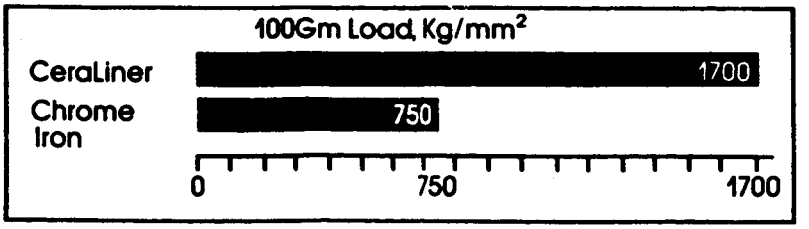
Coors CeraLiners are honed and polished to surface finishes less than 10 microinches R.M.S., more than twice as smooth as chrome iron liners. CeraLiners start smoother and stay smoother than premium chrome iron. The result is more efficient pumping action and up to 3 times the piston life in your mud pump.

Coors CeraLiners are inert and therefore highly resistant to chemical attack. They are not adversely affected by CO_2 or H_2S and virtually impervious to water, solvents, salt solution and molten salts. The corrosion resistance of Coors CeraLiner is far superior to metal liners.

Coors CeraLiner may cost more than your traditional liner but it quickly pays for itself in reduced downtime, labor costs, pump maintenance and continued replacement of liners, pistons and other expendables. It's also lighter than iron to minimize shipping and handling costs.

Next time you need a liner, get three times the life. Contact your mud pump expendables supplier, or direct your inquiries to Coors Ceramics for a list of CeraLiner suppliers.

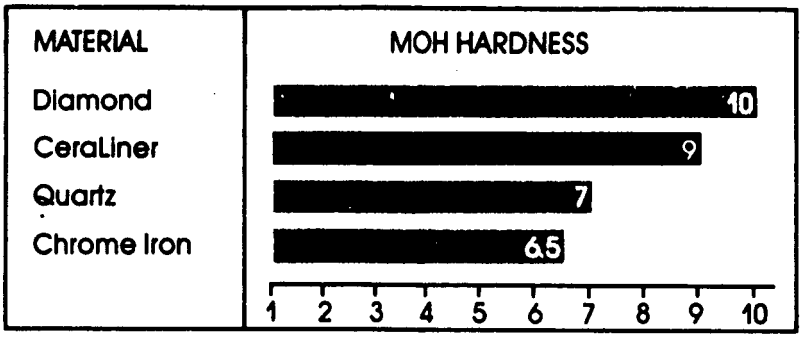
KNOOP HARDNESS



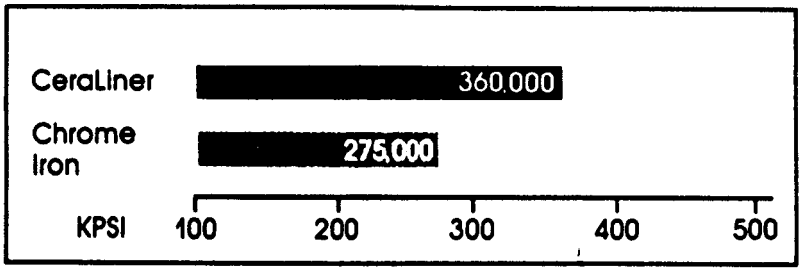
Coors CeraLiner is:
Chemically resistant • Abrasion Resistant • Highly cost effective

Coors CeraLiner is a fine grain material developed for higher performance and greater strength in the most demanding wear and corrosion resistant applications.

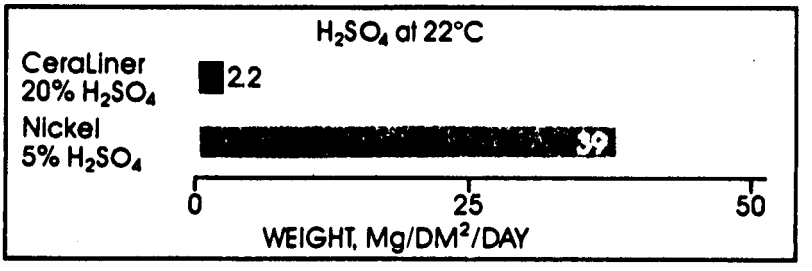
HARDNESS COMPARISON



COMPRESSIVE STRENGTH



CORROSION RESISTANCE, WEIGHT LOSS



CERALINER

Specific Gravity	gm/cm^3	3.60
Knoop Hardness	100 gram load, Kg per mm^2	1700
Crystal Size Average	Micrometers	4
Water Absorption	ASTM C373-72	0
Gas Permeability	Helium test	0
Compressive Strength	MPa (kpsi)	2482 (360)

Coors/CERAMICS

600 9th Street • Golden, CO 80401 • (303) 278-4000 • Tlx: #45593

Operating - KEITH

Changing implements - Me

S1-LO-7

The two link cylinders are the same in all respects. The stoke is 12 inches. All other measurements are as specified.

A= 2.00
B= 1.00
C= 18.75
D= 1.19
E= 1.19
F= 1.06
G= 0.75
H= 0.77
J= 1.50
K= 1.25
L= 2.42
M= 2.19
N= 1.94
P= 1.62
R= 16.50
S= #6(9/16*18)

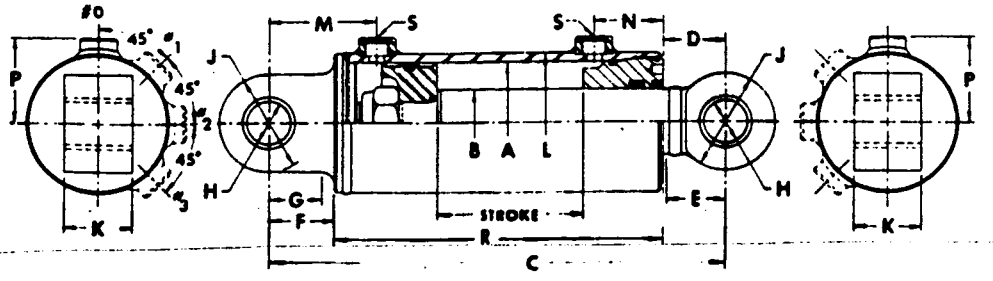
The lift cylinder measurements are as specified.

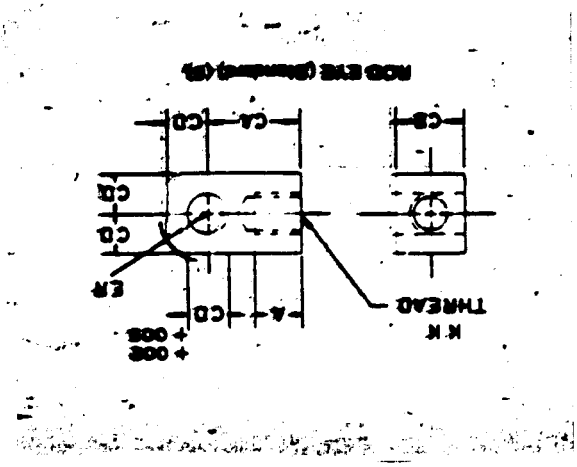
A= 3.00
B= 1.50
C= 19.5
D= 1.56
E= 1.56
F= 1.50
G= 1.12
H= 1.02
J= 2.25
K= 1.75
L= 3.46
M= 2.88
N= 2.06
P= 2.19
R= 16.44
S= #8(3/4*16)

1394891 BENTON HARBOR ENGINEERING 46C 00160 DK-01-05-03

series 250 dimensions

pressure rating: 2500 p.s.i.





ROD END ACCESSORY DIMENSIONS

THREAD KK -	ROD EYE PART NO.	ROD CLEVIS PART NO.	PIN PART NO.	COUPLER PART NO.	A	AC	CA	CB	CC	CD	CE	CK	CL	CW	DC	DE	EB	L	JC	UE
⅛-28	8422	82262	3658-1	526301-07	⅛	⅛	[illegible]	⅜	[illegible]	½	[illegible]	½	[illegible]	½	[illegible]	1 3/16	[illegible]	⅜	[illegible]	1⅛
⅛-18	8423	82263	3658-2	526301-12	1⅛	1¼	2 1/16	1⅛	2 5/16	¾	2⅛	½	2½	⅝	1 3/16	1⅛	29/32	1	3/32	1¾

VICEROY

Style 1
Rod End

VICEROY

Style 2
Rod End

VICEROY

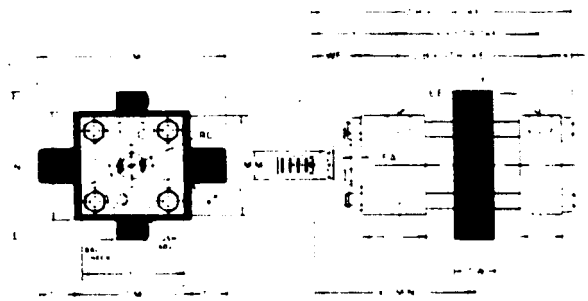
Style 3
Rod End

VICEROY

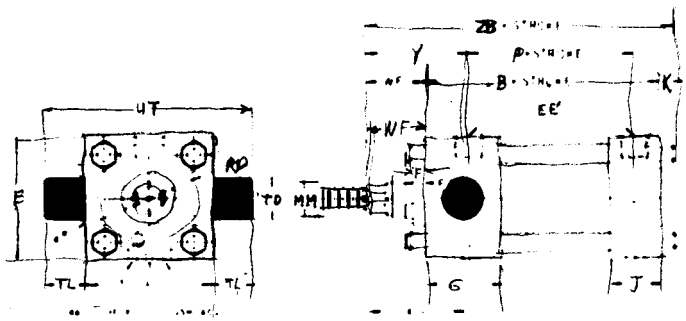
Style 4
Rod End

POOR QUALITY ORIGINAL

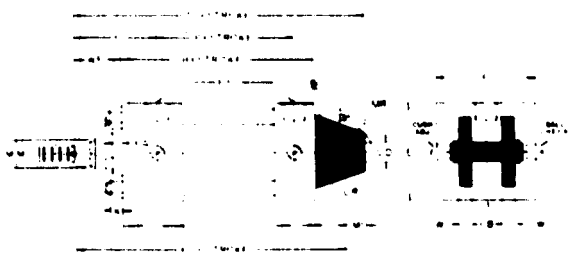
STYLE EB—TRUNNION MOUNT CAP END
(NFPA Mounting Style MT2)



STYLE E—INTERMEDIATE TRUNNION MOUNT
(NFPA Mounting Style MT4)
Customer to Specify Trunnion Location (XI Dim.)



STYLE ER—TRUNNION MOUNT HEAD END
(NFPA Mounting Style MT1)



STYLE G—CLEVIS MOUNT
(NFPA Mounting Style MP1)
Chrome-plated Clevis Pin Assembly (with Snap Rings) is furnished with All Style G Cylinders.

The trunnion pintles on Styles ER and EB are not removable. For information on removable pintles, please consult the engineering department. On all intermediate trunnion mounts the trunnion pintles are an integral part of the mount. All intermediate trunnion mounts are closely fitted into a groove on the cylinder barrel. The position of the intermediate trunnion mount is not adjustable.

NOTE: Cylinders with "ER" mounts in bores 5.0" thru 8" with piston rods other than standard should not be used for pressures in excess of 2000 psi.

Pintles on trunnion-mounted cylinders are designed to withstand shear loads, but not high bending loads. Pillow blocks must be rigidly mounted to provide full support with minimum clearances.

ENVELOPE AND MOUNTING DIMENSIONS

BORE	CB	±.001 CB	CW	E	EE NPTF	EE SAE	G	J	K	L	LR	MR	+.000 −.001 TD	TL	TS	TM	TW	UM	MS	UT	ADD STROKE LB	ADD STROKE P
1½		½		2½		8		1 13/32		⅝		½	1	1	2¾	3	1¼	5	4	4⅞	4⅝	
2	1¼	¾	5/8	3	½	8	1 27/32	1 13/32		1¼		¾	1¾	1 7/16	3¼	3½	1½	6¼	4¾	5¼	4⅝	2 7/8
2½		¾		3½	½	8	1	1 13/32		1½		¾	1¾		3¾	4	1½	6¾	5¼	6¼	4⅝	3
3¼		1		4½		12	2	1 13/16		1½		1	1¾		4¾	5	2	8½	6¼	8	5½	3½
4	2	1¾		5		12	2	1 13/16		2½		1¾	1¾		5¼	5½	2	9	7¼	8½	5⅝	3½
5	2	1¾		6½		12	2	1⅞		2½	2	1¾	1¾		6¾	7	2	10½	9	10	6¼	4
6	2½	2		7½	1	16	2½	2¼		2½	2½	2	2	2	7¾	8½	3	12	10¼	11½	7⅝	5
7	3	2½		8½		20	2½	2¾		3	3	2½	2½	2½	8¾	9½	3	14½	11½	13½	8½	5
8	3	3		9½		24	3	3		3¼	3½	2¾	3	3	10	11	3½	17	12¾	15	9½	6½

Head end cushions are non-adjustable on 1½"-2"-2½" bore cylinders with max. size rods. NPTF ports furnished as standard unless otherwise specified. SAE straight thread ports optional.

PRINTED IN U. S. A.

TWO-AND FOUR-WAY DIRECTIONAL VALVES -SOLENOID OPERATED

SERIES DG4S2-01 & DG4S4-01
NFPA-D02 (ISO-4401-5) INTERFACE
MANIFOLD OR SUBPLATE MOUNTING

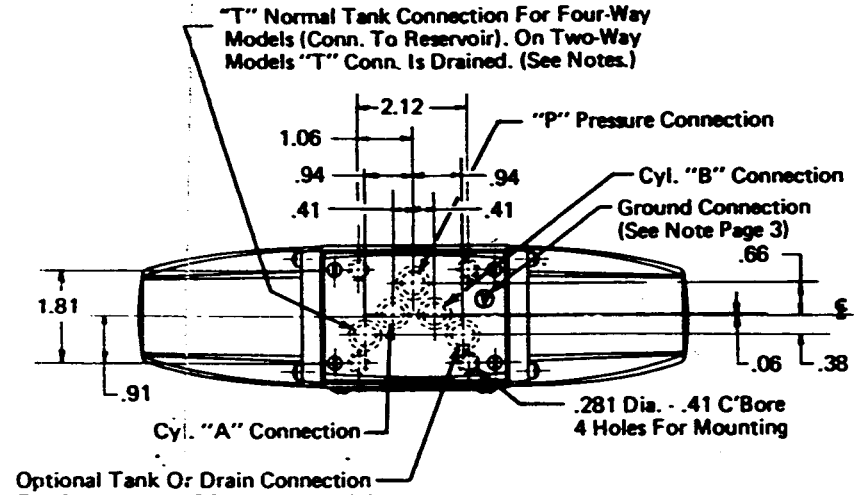
General Data

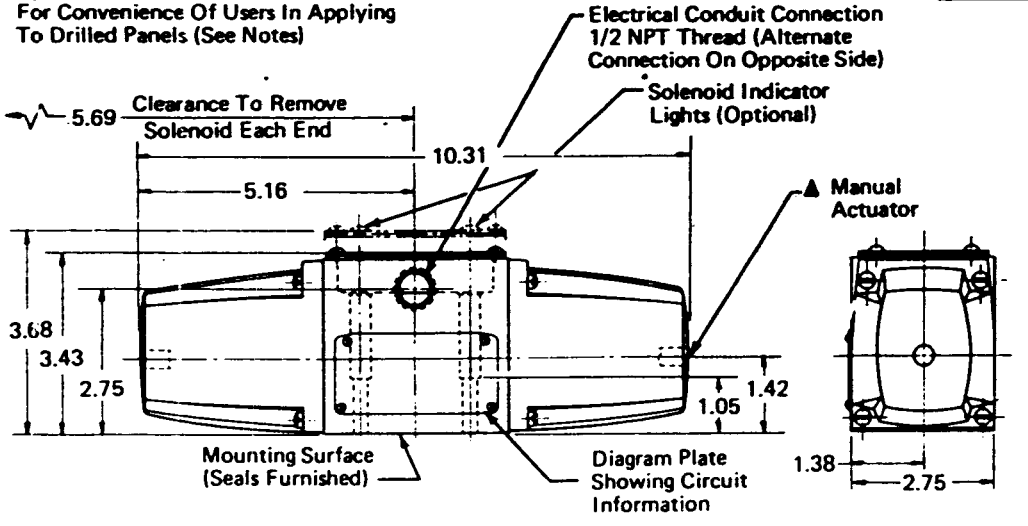
The primary function of these four-way directional valves in a hydraulic circuit is to direct fluid flow. This, in turn, would determine the direction of movement of a fluid cylinder, or the direction of rotation of a fluid motor.

Ratings

Recommended Flow Capacity. . . . . See Chart Page 517401A-4
The above is subject to change if the two following ratings approach maximum value simultaneously. Contact your local Sperry Vickers representative with all particulars and request correct figure if this should occur.

Maximum Operating Pressure (PSI). 3000
Maximum Tank Line Pressure. . . . . See Chart Page 517401A-4

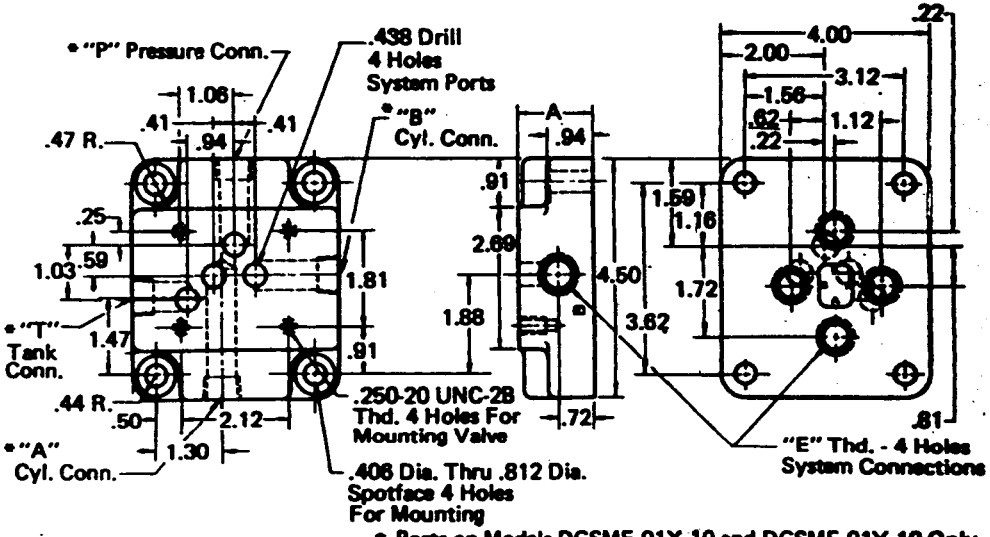

"T" Normal Tank Connection For Four-Way Models (Conn. To Reservoir). On Two-Way Models "T" Conn. Is Drained. (See Notes.)
2.12
1.06
.94
.41
"P" Pressure Connection
Cyl. "B" Connection
Ground Connection (See Note Page 3)
.66
1.81
.91
.06
.38
Cyl. "A" Connection
.281 Dia. - .41 C'Bore 4 Holes For Mounting
Optional Tank Or Drain Connection For Convenience Of Users In Applying To Drilled Panels (See Notes)



DOUBLE SOLENOID, NO-SPRING DETENTED & SPRING CENTERED MODELS

▲ All Valves With The Exception Of Those Having Hazardous Duty Solenoids Have Manual Actuators.

MOUNTING SUBPLATES



* Ports on Models DGSME-01X-10 and DGSME-01Y-10 Only

Model Numbers	"E" Thread	Dimension "A"
DGSM-01X-10	3/8 NPTF	1.25
DGSM-01Y-10	1/2 NPTF	1.25
● DGSM-01Z-10	3/4 NPTF	1.25
DGSM-01-8S-20	.750-16 UNF-2B	1.25
* DGSME-01X-10	3/8 NPTF	1.50
* DGSME-01Y-10	1/2 NPTF	1.50

Subplates and Bolt Kits

Valves, subplates and mounting bolts must be ordered separately.

Example: One (1) DG4S4-012C-50 Valve
One (1) DGSM-01X-10 Subplate
One (1) BKDG01-633 Bolt Kit

Maximum Recommended Mounting Bolt Torque. . . . . 112 lbf-in

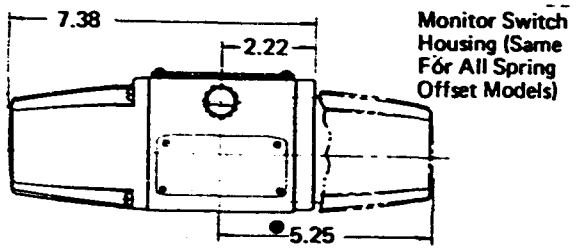
Note: Order bolt kit BKXDG01-634 for valves for hazardous locations and mining applications.

Side connection subplates also are available with 3/8" and 1/2" pipe threads. See drawing no. 522600 in accessory section.

When subplate is not used, a machined pad (as indicated by subplate shaded area) must be provided for mounting; pad must be flat within .0005 inch and smooth within 63 microinch. Mounting bolts, when provided by customer, should be SAE grade 7, or better.

For interchangeability with 1/4" size DG-02 valves and some other brands, see drawing 517500 in accessory section.

SINGLE SOLENOID, SPRING-OFFSET MODELS DG4S2-012A-50 & DG4S4-012A-50 & SDG4S*-01* WITH MONITOR SWITCH



Spring offset models – when solenoid is de-energized, the spool is returned to the offset position.

● Dimension for spring offset model with monitor switch. Models SDG4S2-012A-50 & SDG4S4-012A-50.

Integral monitor switch permits electrical interlocking of various hydraulic controlled motions without resorting to external mechanical contrivances. Switch monitors valve spool position and may be wired into control circuit.

Monitor switch data: Plunger type – panel mounting – single pole – double throw contact arrangement – "A" normally closed – "B" normally open.

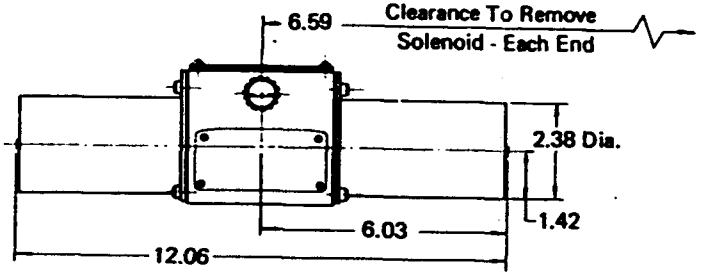
Monitor switch housing does not provide for manual operation.

Electrical Ratings

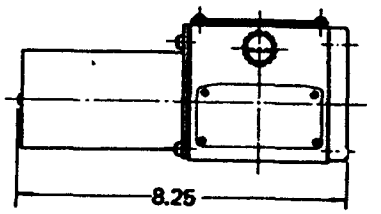
Volts	AC amp	DC amp
28	20	10
125	20	0.5
250	20	0.2
480	20	
600	5	

VALVES WITH DC SOLENOIDS

DOUBLE SOLENOID, NO-SPRING DETENTED & SPRING CENTERED MODELS

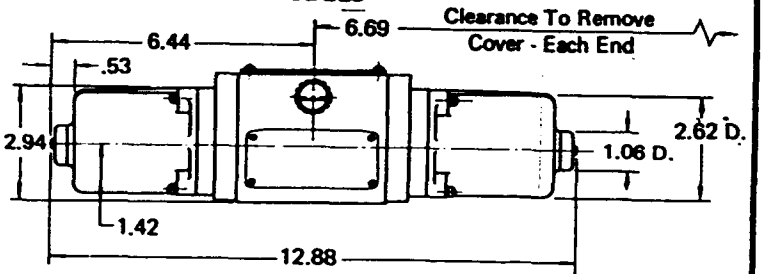


SINGLE SOLENOID, SPRING OFFSET MODEL

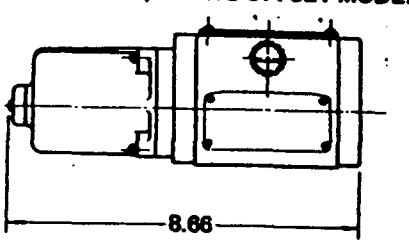


VALVES WITH OIL IMMERSED SOLENOIDS

DOUBLE SOLENOID, NO-SPRING DETENTED & SPRING CENTERED MODELS

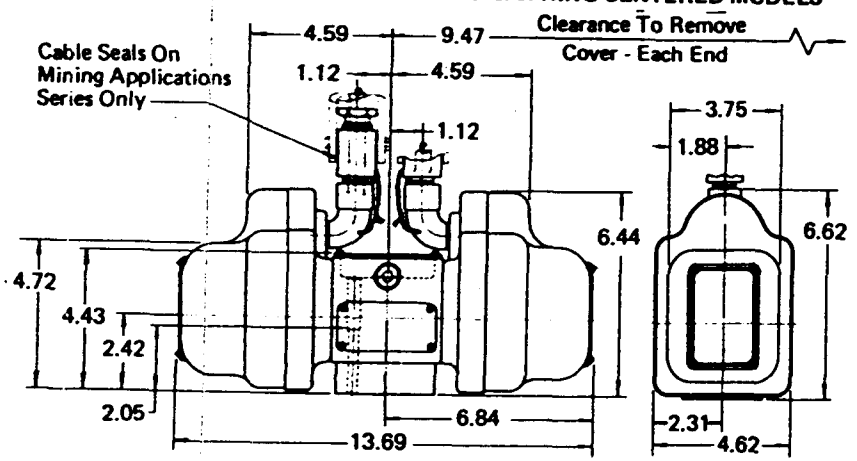


SINGLE SOLENOID, SPRING OFFSET MODEL

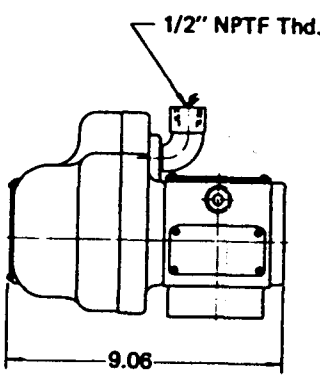


VALVES FOR HAZARDOUS LOCATIONS & MINING APPLICATIONS

DOUBLE SOLENOID, NO-SPRING DETENTED & SPRING CENTERED MODELS



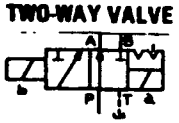
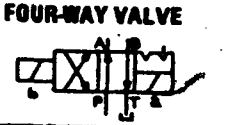
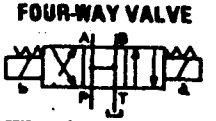
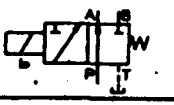
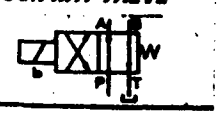
SINGLE SOLENOID, SPRING OFFSET MODEL



Valves have "UL Listed" solenoids for use in hazardous locations – Class I Group D, Class II Group E-F-G, for 115 and 230 Vac, 60 Hz service.

Valves for Mining Applications are built to MSHA Schedule 2G-File X/P837-2. Available in all standard voltages.

TYPICAL GRAPHICAL SLIDING SPOOL SYMBOLS

NO-SPRING DETENTED	TWO-WAY VALVE 	FOUR-WAY VALVE 
SPRING CENTERED	FOUR-WAY VALVE 	
SPRING OFFSET	TWO-WAY VALVE 	FOUR-WAY VALVE 

Note: When solenoid "a" is energized flow is always P→A. When solenoid "b" is energized, flow is always P→B. Spring Offset valves as shown (not LH) flow P→A in the offset position. Solenoid "a" and "b" are identified on the diagram plate.

Model Number			Spool Type	Spool Center Position	Description	Pressure Drop bar (PSI) @ 37.85 litres/min (10 GPM)					Maximum Tank Line Back Pressure bar (PSI)
No-Spring Detented	Spring Centered	Spring Offset				P→A	B→T	P→T	A→T	P→T Cent.	
DG4S4*-010N-51	DG4S4*-010C-50	DG4S4*-010A-50	0		Open Center All Ports	1.93 (28)	1.65 (24)	1.93 (28)	2.28 (33)	2.28 (33)	At Time Spool Shift Is Required 68 (1000) At Time Spool Shift Is Not Required 204 (3000)
	DG4S4*-011C-50	DG4S4*-011A-50	1		Open Center P & A	2.14 (31)	2.41 (35)	2.14 (31)	2.56 (37)		
DG4S4*-012N-51	DG4S4*-012C-50	DG4S4*-012A-50	2		Closed Center All Ports	2.14 (31)	2.41 (35)	2.14 (31)	2.76 (40)		
	DG4S4*-013C-50		3		Closed Center P & B	2.14 (31)	2.41 (35)	2.14 (31)	2.28 (33)		
DG4S4*-016N-51	DG4S4*-016C-50	DG4S4-016A-50	6		Closed Center P Only	2.14 (31)	1.65 (24)	2.14 (31)	2.28 (33)		
DG4S4*-017N-51	DG4S4*-017C-50		7		Open Center T Blocked	1.93 (28)	2.28 (33)	1.93 (28)	2.76 (40)		
	DG4S4*-018C-50		8		Tandem Open Crossover	1.45 (21)	1.65 (24)	1.45 (21)	1.93 (28)	4.48 (65)	
DG4S4*-0133N-51	DG4S4*-0133C-50		33		Closed Center Bleed A & B	2.14 (31)	2.28 (33)	2.14 (31)	2.76 (40)		
DG4S2-012N-50		DG4S2-012A-50	2		Closed Center Crossover	2.14 (31)	Blocked	2.14 (31)	Blocked		3.45 (50) Drain Do Not Plug Tank Port

Note: When solenoid "a" is energized, flow is always P→A. When solenoid "b" is energized, flow is always P→B. Spring offset valves as shown (not LH) flow P→A in the offset position. Solenoid "a" and "b" are identified on the diagram plate.

Ratings. . . . . See Above

Maximum flow is dependent upon the valve type used and is subject to variation due to changes in operating pressure or tank line back pressure. If operating pressure and tank line back pressure simultaneously approach maximum, or if higher flow rates are desired, contact the Sperry Vickers representative in your area.

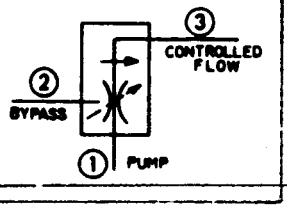
Maximum Operating Pressure (PSI). 3000
Maximum Tank Line Pressure. . . . . See Above

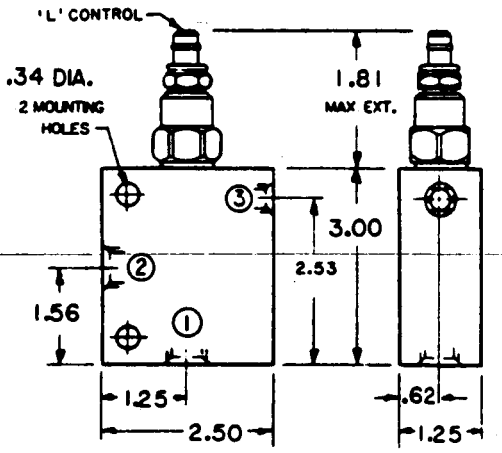
Flow Ratings

Valve Type	Spool Type	Recommended Flow Capacity litres/min (GPM)	Maximum Flow Without Malfunction litres/min (GPM)
No-Spring Detented 4-Way	0,2,6,7,33	38 (10)	76 (20)
Spring Centered	0,2,3,6,7,33		
Spring Offset 4-Way	0, 2, 6		
Spring Centered	8	30.3 (8)	45.5 (12)
Spring Centered	1	18.8 (5)	18.8 (5)
No-Spring Detented 2-Way	2	11.3 (3)	11.3 (3)
Spring Offset 2-Way			

BYPASS & RESTRICTIVE COMBINATION

LINE MOUNTED



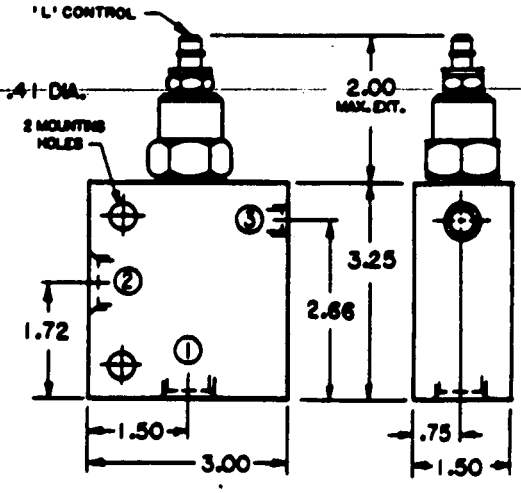


MAIN PORTS ① ②	CONTROLLED FLOW PORT ③	BASIC VALVE MODEL (a)	BASIC PRICE (a)
¼" NPTF	⅛" NPTF	FRCA *A* ECA	34 30
⅛" NPTF	⅛" NPTF	FRCA *A* EAB	35 30
⅛" NPTF	¼" NPTF	FRCA *A* ECB	34 30
½" NPTF	⅛" NPTF	FRCA *A* EAC	35 30
½" NPTF	¼" NPTF	FRCA *A* ECC	34 30
SAE -6	SAE-6	FRCA *A* ECI	34 30
SAE- 8	SAE-8	FRCA *A* EAJ	35 30
SAE- 8	SAE-6	FRCA *A* ECJ	34 30
SAE-10	SAE-8	FRCA *A* EAK	35 30
SAE-10	SAE-6	FRCA *A* ECK	34 30

MODEL **FRCA *A* E** **

See **FRCA** Cartridge Model Coding (p. 9.10)

PORTS SEE CHART



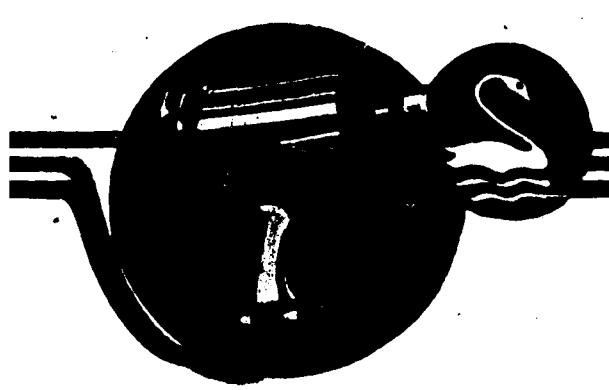
MAIN PORTS ① ②	CONTROLLED FLOW PORT ③	BASIC VALVE MODEL (a)	BASIC PRICE (a)
½" NPTF	½" NPTF	FRDA *A* BAC	50 20
¼" NPTF	½" NPTF	FRDA *A* BAD	50 20
⅛" NPTF	¼" NPTF	FRDA *A* BCD	48 20
SAE-10	SAE-10	FRDA *A* BAK	50 20

MODEL **FRDA *A* B** **

See **FRDA** Cartridge Model Coding (p. 9.10)

PORTS SEE CHART

(a) See cartridge models FRCA *** and FRDA *** (page 9.10) for performance data, options and option prices.



SAE 100R3 Hydraulic Hose

A medium pressure hydraulic hose suitable for use with petroleum and water base fluids and with oils, lubricating oils and gasoline. Ideal for high pressure car washes and diver's hose. MSHA Approved.

TUBE: Nitrile; heat and oil resistant rubber compound.

REINFORCEMENT: Braided synthetic cord

COVER: Black Neoprene; heat and flame retardant rubber compound.

SERIES 57-750

Size I.D. In.	Approx. O.D. In.	Reinforced with synthetic cord	W.P. PSI	Approx. Wt./Lbs. C/Ft.
1/4	9/16	2 Braid	1250	14.1
3/8	3/4	2 Braid	1125	20.5
1/2	15/16	2 Braid	1000	30.3
3/4	1 1/4	2 Braid	750	46.7
1	1 1/2	2 Braid	565	58.3

SAE 100R7 Hydraulic Hose

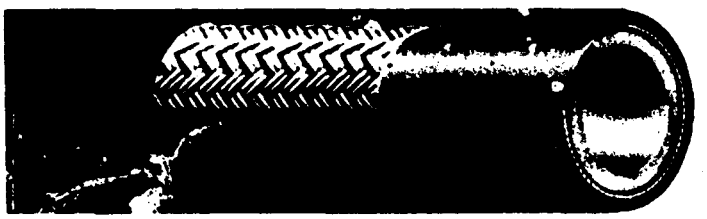
Suitable for use in construction equipment and machinery with petroleum, water base and synthetic hydraulic fluids within a temperature range of – 65°F. to + 250°F. Good for applications subject to severe external conditions where minimum bend radius is important. Withstands severe vibration, flexing and impact.

TUBE: Chemical and oil resistant smooth bore high temperature Hytrel.®

REINFORCEMENT: Braided synthetic cord

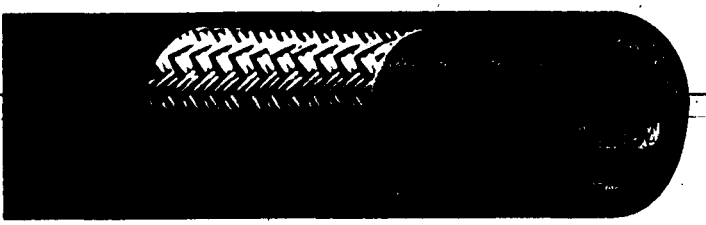
COVER: Heat and oil resistant Hytrel.®

SERIES 58-100 CONDUCTIVE — COLOR BLACK



Size I.D. In.	Approx. O.D. In.	Reinforced with synthetic cord	W.P. PSI	Approx. Wt./Lbs. C/Ft.
3/16	27/64	2 Braid	3000	7.7
1/4	31/64	2 Braid	2750	9.7
5/16	35/64	2 Braid	2500	11.6
3/8	41/64	2 Braid	2250	14.6
1/2	51/64	2 Braid	2000	25.5

SERIES 58-200 NON-CONDUCTIVE — COLOR ORANGE



Size I.D. In.	Approx. O.D. In.	Reinforced with synthetic cord	W.P. PSI	Approx. Wt./Lbs. C/Ft.
3/16	27/64	2 Braid	3000	7.7
1/4	31/64	2 Braid	2750	9.7
5/16	35/64	2 Braid	2500	11.6
3/8	41/64	2 Braid	2250	14.6
1/2	51/64	2 Braid	2000	25.5

*Reg. TM of DuPont

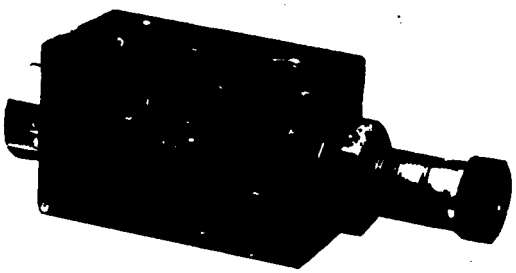
Lubriquip Product Specs & Ordering

Trabon and *Manzel* Lubrication Systems

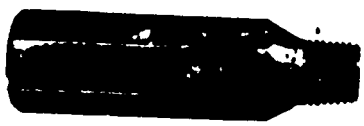
Restrictor Valves

Revised
March, 1980

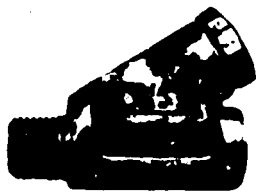
15826



Part Number 542-089-000



Part Number 542-102-001



Part Number 511-895-000

DESCRIPTION

Trabon Restrictor Valves are designed for grease, oil or pneumatic systems with pressures up to 3000 PSI. Direction of flow is generally indicated by an arrow shown on the valve body; if not, the outline drawing of the restrictor valve shown on this sheet will indicate the inlet port side.

The purpose of these valves is to provide suitable restriction of the power source which will eliminate excessive pressure surge. This surge or shock could damage the pump or system components or result in false high pressure signals.

Restrictor Valve, part number 511-895-000, is used on pneumatic and hydraulic automated pumps and lube packages. It consists of a one piece body with internal working parts that restrict forward flow. A compression spring and valve permits free flow in the opposite direction. A 100 mesh filter and a 1/32-inch diameter orifice valve restricts the flow of air or hydraulic fluid to the pump. If the 100 mesh filter becomes clogged with sediment or dirt it can be easily removed and cleaned without disturbing fittings or connections. This restrictor valve is used for oil or air applications.

Restrictor Valve, part numbers 542-089-000 and 542-102-001, are used on oil and grease header lines. Grease type restrictor valve, part number 542-089-000 is based on a screw type principle adjustment valve. Restriction of flow is increased by a clockwise adjustment of the screw. Turning in an opposite direction (counterclockwise) decreases the flow of restriction. A locknut provides a positive set point of adjustment.

Oil type restrictor valve, part number 542-102-001, is factory set and no other adjustment is necessary. Flow is restricted by a threaded restrictor insert lightly pressed into position in the restrictor body.

CAUTION

Care must be taken when adjusting restricting screw so as not to damage the thredseal washer.

FEATURES

0637 D-02

- Tamper-proof (P/N 511-895-000 and 542-102-001).
- Compact and durable.
- Simple installation (2 connections).
- Shockproof under extreme surging.
- Precise metering control.
- May be mounted in any position.

SPECIFICATIONS

Material (Body) . . . . . Steel
Pressure (Maximum) . . . 3000 PSI (210.9 kg/cm²)
Lubricant: . . . . . Restrictor Valve
Oil or Air 511-895-000
Grease 542-089-000
Oil 542-102-001
Ambient Temperature Range . . . . . – 65° F to + 180° F (– 53° C to + 82° C)
Net Weight (Approximate) . . . . . Restrictor Valve
4 ozs. (0.11 kg) 511-895-000
3-1/2 lbs. (1.58 kg.) 542-089-000
5 ozs. (0.14 kg.) 542-102-001

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GENERAL AEROSPACE MATERIALS CORPORATION
95 EAST BETHPAGE ROAD, PLAINVIEW, N.Y. 11803

ALUMINUM TUBING

OD	WALL	LBS. PER FT.	WWT 700/3	WWT 700/2	WWT 700/4	WWT 700/6	MILT 7081
1/8 [.125]	.020	.0936					60
3/16 [.188]	.020	.013					196
	.035	.020	2,400		108	2,400	240
1/4 [.250]	.028	.023			1,600		300
	SCH 40	.147				1,200	
	.035	.028	3,600		5,000	5,000	3,000
	.049	.036				6,000	
	.065	.0444			600		
5/16 [.313]	.035	.036	2,400		3,000	5,000	
	.042	.041				1,400	
	.049	.048	1,200		1,200	3,000	
	.058	.055				2,400	
3/8 [.375]	.028	.036			4,000		
	.035	.044			5,000	2,000	716
	.049	.059	3,000		180	3,000	240
	.058	.068				3,000	
	.065	.074				500	
7/16 [.438]	.049	.070				3,000	
	.065	.089				3,000	
	.120	.141				2,400	
1/2 [.500]	.035	.060	5,000	1,200	3,600	3,600	1,200
	.049	.082				3,600	480
	.058	.095				3,000	
	.065	.104			600	2,400	
	.083	.128				1,800	
	.095	.142	96				
5/8 [.625]	.028	.062			1,200		
	.035	.076			600	2,400	1,060
	.049	.104	1,200			2,400	400
	.058	.121				1,800	
	.065	.134				2,000	
	.125	.231				600	
3/4 [.750]	.028	.0747			4,000		
	.035	.093	2,400		720	2,400	700
	.049	.127	5,000		2,400	2,100	1,200
	.058	.148				1,200	
	.065	.164	1,200			1,200	600
	.083	.205	1,200			600	
	.095	.230	900				
7/8 [.875]	.035	.109				1,800	
	.049	.150				1,500	
	.058	.175				1,800	
	.065	.194				1,200	

A Record of Invention is a very important legal document, and proper care in its early and complete preparation will save much time and inconvenience in the future should the invention ever become involved in a controversy. Separate Record of Invention forms must be prepared for each distinct invention. This Record of Invention form was prepared to fit all possible conditions and therefore contains questions which may not be applicable to certain inventors. If a question cannot be answered, mark it "does not apply," "no" or "none," etc.

1. Give name in full - JOHN ALLEN DOE or JOHN A. DOE, and position. J. ALLEN DOE will not be accepted by the Patent Office.

2. Give complete details - name, address, phone and extension, city, state.

3. Indicate date first employed.

4. Give your present address. This is your residence address.

5. If No. 4 is a temporary address, give a permanent address where mail can be sent and forwarded regardless of your temporary location. If No. 4 is your permanent address, No. 5 may be marked "Same as No. 4."

6. The question as to whether an invention was actually conceived by one person or by the cooperation of several persons is vitally important to the validity of the patent. Incorrect decisions of sole or joint inventorship will result in an *invalid patent*. Personal feelings and friendships must not influence the answer to this question. To merely present a problem does not make one an inventor. He must contribute to the solution of the problem to be classed as an inventor. A mechanic who builds a device under the supervision of an inventor is not a joint inventor. If there is any doubt, obtain assistance.

7. A short title briefly describing the invention. For instance, "Method and Apparatus for Preparing Segmental Carbon Rings," "Uni-directional Antenna," or "Packing Gland Wrench."

8. A list is desired of all pertinent material which forms the "Disclosure of Invention," thereby relating the Record of Invention to the disclosure. Give accurate print reference numbers, photo numbers, etc., identifying sketches by date and/or some other reference.

9. This is the date on which the general "idea" was "born". State briefly circumstances relative to conception. For example, on 2 February 1945, I saw accident to John A. Doe while working on circular saw and need for a guard was apparent. Immediately made sketch for a suitable guard and presented it to James Smith, my foreman. Or, test for signal generator was unsuccessful for several months. On 21 January 1946 made change in circuit by changing capacity and location of by-pass condensor and installing suitable chokes.

10. This date may coincide with No. 9, will never be earlier, but may be later.

11. This date also may be the same as No. 9 and No. 10, or different from either one, but never earlier than No. 9.

12. The disclosure of the invention may be by orally telling someone of your invention, by showing and explaining descriptions and drawings, or by demonstrating the operation of a model or full scale device. The person(s) to whom an invention is disclosed may make an excellent witness if the invention is ever involved in a controversy and it is to the inventor's advantage to see that his invention is understood. It is preferable to ask the witness to read and sign the description and drawings, using the statement "Disclosed to and understood by my this _____ day of _____ 19___." Notebook entries should be handled in a like manner. Indicate persons' position, connection with outside commercial firm, or other pertinent information. State if orally, by sketch or other form.

13. If no model or full scale device was made, so state. Answers to Nos. 14 to 18 inclusive should be marked "does not apply."

14. Indicate where model or full scale device may be seen in the event the attorney desires to witness its operation.

over

15. State whether first tests were successful or unsuccessful and briefly outline results.

16. Witnesses to tests are important. Identify them so they can be located later if necessary.

17. Tell briefly results of later tests, and give data on witnesses.

18. It is desirable to record carefully the results of all tests and to preserve such records. A copy of these test results may form a part of the invention disclosure to assist the attorney in preparing the case.

19. In related inventions, much repetition can be avoided by reference to the previous invention(s), if any. Identify such records or reports by title, inventor, date, number, etc.

20. Most inventions are improvements over existing devices. References to the devices which have been improved are very helpful to the attorney preparing the patent application. Such references may consist of patent numbers, issued patents, pending applications, articles published in technical magazines, listing in catalogs or trade journals, or any other published record of the invention.

21. The law provides that after an invention has been in "Public Use" for more than one year it becomes public property and cannot be protected by Letters Patent. The question of public use is a debatable one. The same is true of experimental use, and it is sometimes difficult to ascertain when experimental use ceases and public use begins. A statement as to the use of your invention with sufficient details as to the circumstances will assist in determining whether public use exists. Differentiate, if possible, between use by the Government and commercial use.

22. Where details of the invention have been released to a firm or activity, it is important to record the data to clearly fix the facts of the release of information. The firm may be under contract with a federal agency. If so, the contract number should be given.

23. If classified, the proper classification is to be stamped on both the top and bottom of each page.

RECORD OF INVENTION - Part I

This is an important legal document. Read instructions carefully before filling in data.

PROJECT NO. _____

CONTRACT NO. _____ RECOMMENDED SECURITY CLASSIFICATION _____ REC. OF INV. NO. _____

1. NAME OF INVENTOR: Steven R. Hahn — POSITION: Student

2. DEPARTMENT OR DIVISION: Mechanical Engineering

3. DATES OF EMPLOYMENT: 5-80 to present

4. PRESENT ADDRESS (No. Street, City, County, State): 500 Northside Cir. Atlanta, Ga. 30309 — TELEPHONE: (404) 351-5261 — PERMANENT OR UNTIL:

5. PERMANENT ADDRESS (No. Street, City, County, State): 8408 Wexford Rd Marlton, Md. 20772 — TELEPHONE: (301) 627-2839

6. NAMES (S) AND ADDRESS (ES) OF CO-INVENTORS (If any)

Keith Mazena — Maureen Milici

Mike Bender — Tom Whittaker

Sam Richter (Addresses unavailable)

7. DESCRIPTIVE TITLE OF INVENTION

Contour following hitch with remotely controlled lift, pitch, and yaw

8. LIST DRAWINGS, SKETCHES, PHOTOS, REPORTS, DESCRIPTIONS, NOTEBOOK ENTRIES, ETC. WHICH SHOW OR DESCRIBE INVENTION

Nasa / University Advanced Design Concepts, Kinematic Hitch Dwgs

9. EARLIEST DATA AND PLACE INVENTION WAS CONCEIVED (Brief outline of circumstances)

Conceived April 20 during group brainstorming session

10. DATE AND PLACE OF FIRST SKETCH, DRAWING OR PHOTO

May 15, Georgia Institute of Technology

11. DATE AND PLACE OF FIRST WRITTEN DESCRIPTION

May 15, Georgia Institute of Technology

12. DISCLOSURE OF INVENTION TO OTHERS

NAME, TITLE AND ADDRESS	FORM OF DISCLOSURE	DATE AND PLACE OF DISCLOSURE	WAS SIGNATURE OBTAINED (YES OR NO)
James Brazell	dwgs.	May 25, Georgia Tech	No

12.A IMPORTANT - HAVE ANY PUBLICATIONS OR REPORTS BEEN MADE ON THIS INVENTION? No

13. DATE AND PLACE OF COMPLETION OF FIRST OPERATING MODEL OR FULL SIZE DEVICE N/A

14. PRESENT LOCATION OF MODEL N/A

15. DATE, PLACE, DESCRIPTION AND RESULTS OF FIRST TEST OR OPERATION N/A

16. NAMES AND ADDRESSES OF WITNESSES OF FIRST TEST N/A

17. DATE, PLACE, DESCRIPTION AND RESULTS OF LATER TESTS (name witnesses) N/A

18. IDENTIFY RECORDS OF TESTS AND GIVE PRESENT LOCATION OF RECORDS N/A

19. PRIOR REPORTS OR RECORDS OF INVENTION TO WHICH INVENTION IS RELATED None

20. OTHER KNOWN CLOSELY RELATED PATENTS, PATENT APPLICATIONS AND PUBLICATIONS

PATENT OR APPLICATION NO.	DATE	TITLE OF INVENTION OR PUBLISHED ARTICLE	NAME OF PUBLICATION

21. EXTENT OF USE: PAST, PRESENT AND CONTEMPLATED (Give dates, places and other pertinent details)

22. DETAILS OF INVENTION HAVE BEEN RELEASED TO THE FOLLOWING COMPANIES OR ACTIVITIES

NAME AND ADDRESS	INDIVIDUAL OR REPRESENTATIVE	CONTRACT NO.	DATE
Georgia Tech, Atlanta, Ga.	James Brazell		

SIGNATURE OF INVENTOR Steven R. Hahn DATE 6-7-85

RECORD OF INVENTION - Part II

(Attach to Record of Invention Part I)

REC. OF INV. NO. _____

This Disclosure of Invention should be written up in the inventor's own words and generally should follow the outline given below. Sketches, prints, photos and other illustrations as well as reports of any nature in which the invention is referred to, if available, should form a part of this disclosure and reference can be made thereto in the description of construction and operation.

1. INVENTORS NAME(S)
Sam Richter, Steven R. Hahn, Keith Mozena, Tom Whittaker, Maureen Milici, Mike Bender.

2. TITLE OF INVENTION
Lunar Kinematic Hitch

For answers to following questions use remainder of sheet and attach extra sheets if necessary.

3. GENERAL PURPOSE OF INVENTION. STATE IN GENERAL TERMS THE OBJECTS OF THE INVENTION.

4. DESCRIBE OLD METHOD(S) IF ANY, OF PERFORMING THE FUNCTION OF THE INVENTION.

5. INDICATE THE DISADVANTAGES OF THE OLD MEANS OR DEVICE(S).

6. DESCRIBE THE CONSTRUCTION OF YOUR INVENTION, SHOWING THE CHANGES, ADDITIONS AND IMPROVEMENTS OVER THE OLD MEANS OR DEVICES

7. GIVE DETAILS OF THE OPERATION IF NOT ALREADY DESCRIBED UNDER 6.

8. STATE THE ADVANTAGES OF YOUR INVENTION OVER WHAT HAS BEEN DONE BEFORE.

9. INDICATE ANY ALTERNATE METHODS OF CONSTRUCTION.

10. IF A JOINT INVENTION, INDICATE WHAT CONTRIBUTION WAS MADE BY EACH INVENTOR.

11. FEATURES WHICH ARE BELIEVED TO BE NEW.

12. AFTER THE DISCLOSURE IS PREPARED, IT SHOULD BE SIGNED BY THE INVENTOR(S), AND THEN READ AND SIGNED AT THE BOTTOM OF EACH PAGE BY TWO WITNESSES USING THE FOLLOWING STATEMENT:
"DISCLOSED TO AND UNDERSTOOD BY ME THIS_____DAY OF_____19___
SIGNATURE_____."

3) This hitch is for use in the lunar enviroment providing contour follow, lift, pitch and yaw control by remote control.

4) None known of.

5) Old means are not remotely controlled, a necessity for lunar application.

6) Construction is similar to existing hitches, but it is lighter using Al 2218 and strength efficient geometries. Old means of design are much heavier and bulkier.

7) N/A

8) See above

9) N/A

REC. OF
INV. NO. _____

10) All inventors contributed equally in all phases of design.

11) None

Steven R. Kahn
INVENTOR
June 2 19 85

DISCLOSED TO AND UNDERSTOOD BY ME
ON THIS _____ DAY OF _____ 19____
_____
WITNESS

DISCLOSED TO AND UNDERSTOOD BY ME
ON THIS _____ DAY OF _____ 19____
_____
WITNESS

H. Bibliography

1. Evironmental Effects on Materials for Space Applications ,"Fracture Mechanics and Fatigue Criteria in Material Selection for Space Application" Prof. E. Vallerain,Engr.P> Marchese,Engr.G. Banns,September,1982.

2. Space Materials Handbook ,Claus Goetzel,John B. Rittenhouse,John B. Singlelary,Addison and Wesley Publishing Co.,Inc.,1965.

3. Manufacturing Processes for Engineering Materials ,Serope Kalpakjian,Addison and Wesley Publishing Co.,Inc.,1984.

4. Handbook of Stainless Steels ,Peckner & Bernstein,McGraw Hill Book Co.,1977.

5. Alloy Digest ,A1-95,August,1978.

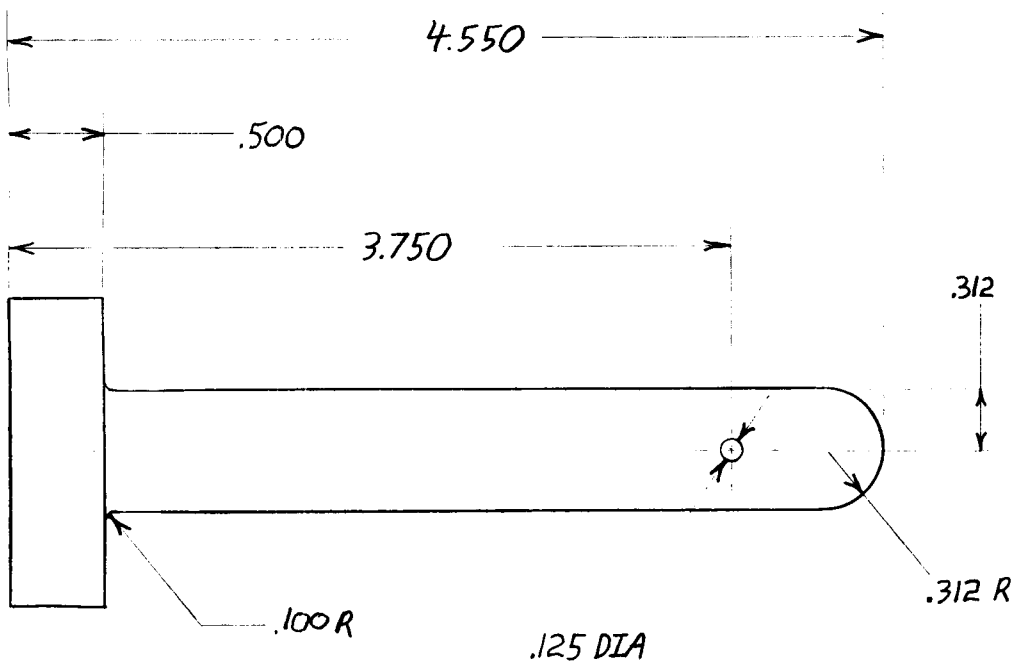
References Used Hydraulic Design

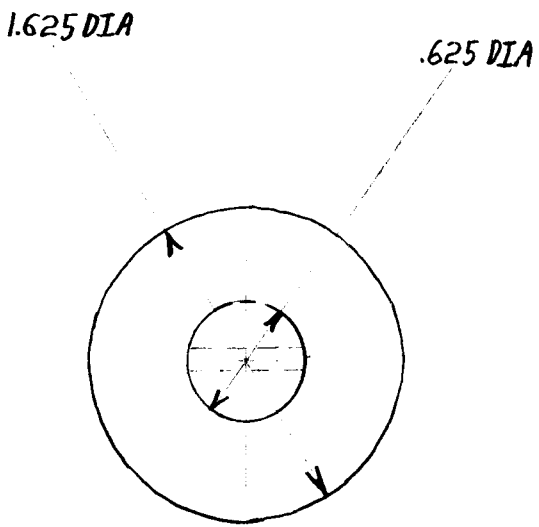
Black, William Z. Basis Heat Transfer. New York: Harper & Row ,1980
Brick, Pence, and Gorden. Structure and Properties of Engineering Materials.New York: McGraw-Hill,1977
Duffie and Beckman. Solar Engineering of Thermal Processes.New York: Wiley-Interscience, 1980
Holzbock, werner. Hydraulic Power and Equipment.New York: Industrial Press,1968
Ernst, Walter. Oil Hydraulics and it Industrial Applications. New York: McGraw Hill, 1960
Shigley and mitchell. Mechanical Engineering Design.New York, 1983
Hyydraulic Handbook.Trade and Technical press.

BILL OF MATERIALS

PART No.	DESCRIPTION	QTY
0000101	MACHINED ALUMINUM HINGE PIN FOR LOWER LINK	2
0000102	MACHINED ALUMINUM HINGE PIN FOR HYDRAULIC LINKS	4
0000103	MACHINED ALUMINUM ROTATION PIN FOR TONGUE	1
0000104-7	CERAMIC LINERS FOR FRICTION POINTS IN LINK	18
0000108	ALUMINUM I-BEAM FOR LOWER LINK	2
0000109	ALUMINUM CROSS BRACE FOR LOWER LINK	1
0000110	ALUMINUM LINK TONGUES FOR LOWER LINK	4
0000111	ALUMINUM MOUNTING BRACKET WITH HINGE FLANGES	1
0000112	ALUMINUM HITCH TONGUE	1
0000113	ALUMINUM COUPLER LINK BOX	1
0000114	ALUMINUM MOUNTING BRACKET FOR LIFT CYLINDER	1

0000101





NASA/ UNIVERSITY
ADVANCED DESIGN CONCEPTS

TITLE: HINGE PIN - LOWER LINK

TOLERANCE UNLESS OTHERWISE NOTED:

IN: .050 MM:

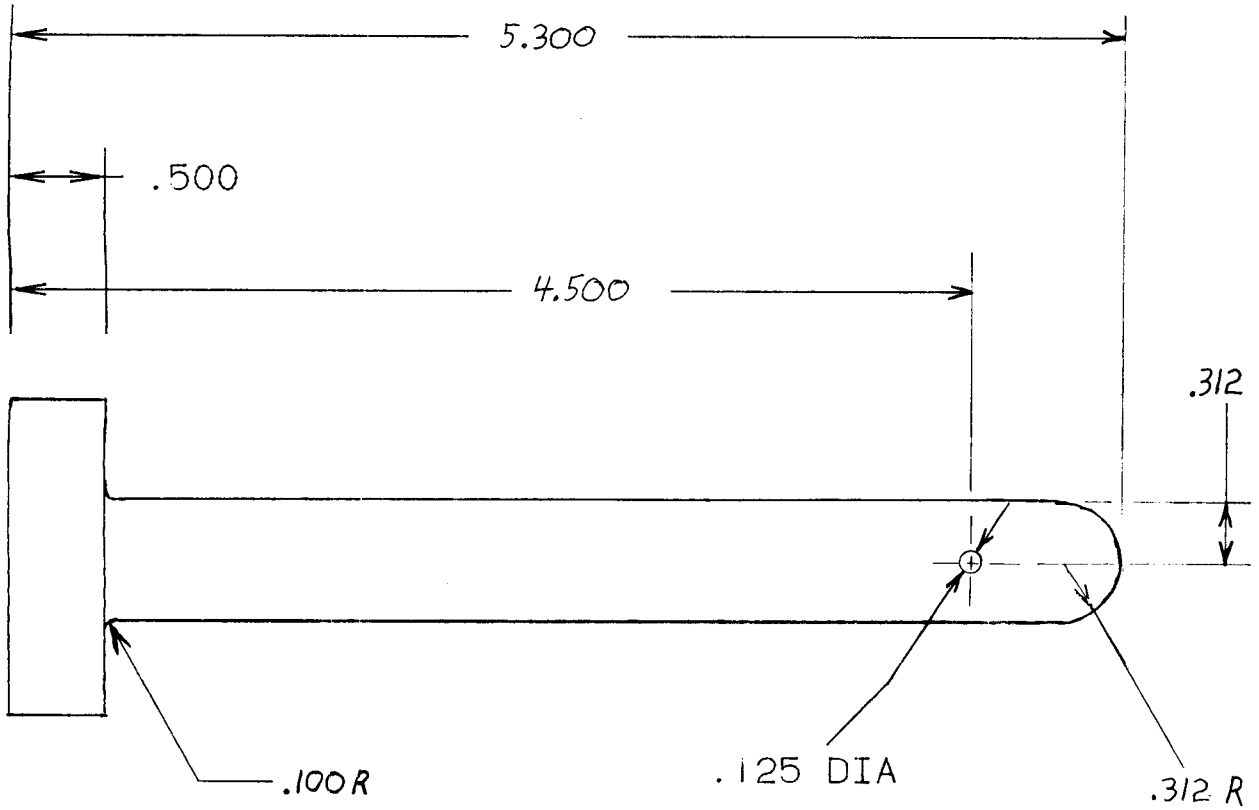
DESIGN: No. 1 DATE: 5/30/85

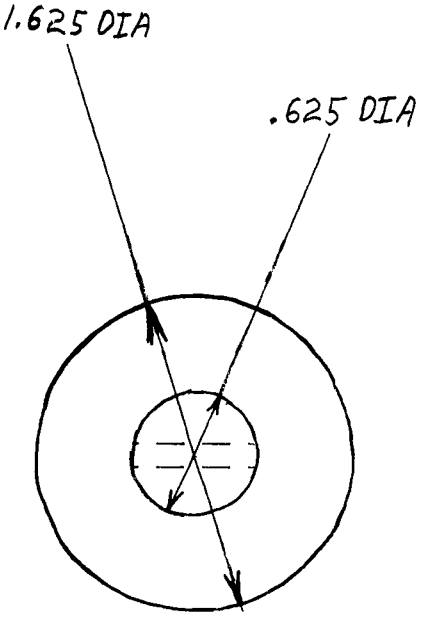
MATL: AL 2218 CHECK: DATE:

SCALE: 1.00:1.00 DRWG No. 1 OF 1

0000101

0000102





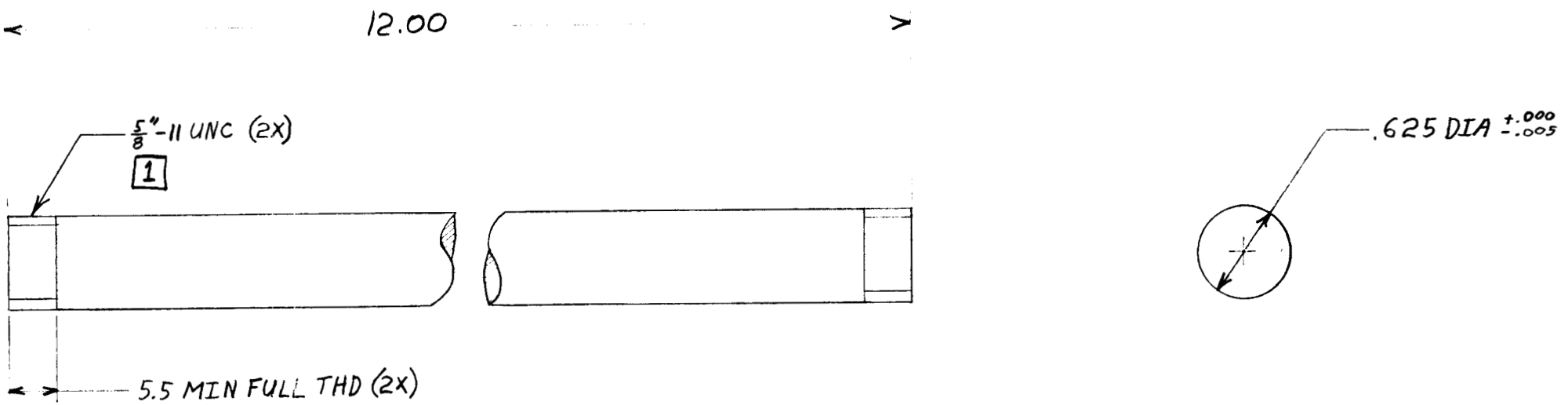
	NASA / UNIVERSITY ADVANCED DESIGN CONCEPTS
TOLERANCE UNLESS OTHERWISE NOTED:	TITLE: HINGE PIN – *HYDRAULIC LINKS*
IN: .050 MM:	
MATL: AL 2218	DESIGN: NO. 2 DATE 5/30/85
SCALE: 1.00 · 1.00	CHECK: DATE
	DRWG NO. 1 OF 1

0000102

0000103

NOTES:

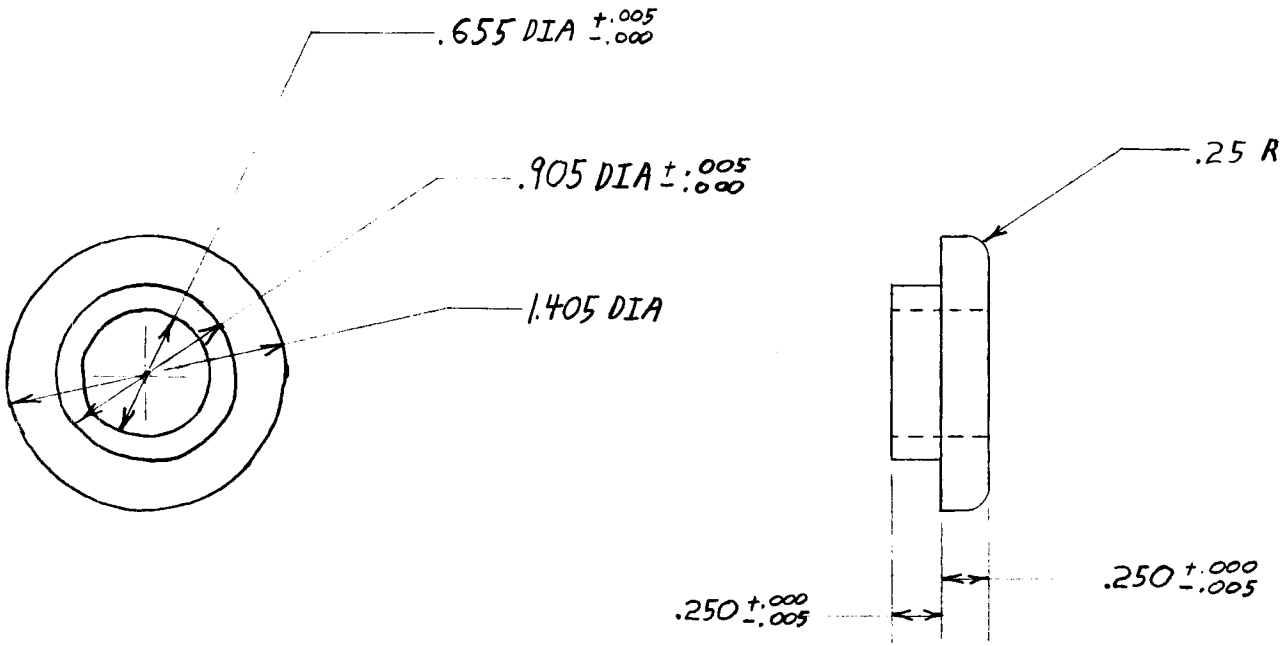
[1] USE LOCTITE TYPE OF NUT



	NASA/ UNIVERSITY ADVANCED DESIGN CONCEPTS
TOLERANCE UNLESS OTHERWISE NOTED:	TITLE: AXEL - TONGUE ROTATION
IN: .050 MM:	DESIGN: No. 1 DATE: 5/30/85
MATL: AL 2218	CHECK: DATE:
SCALE: 1.000 : 1.000	DRWG NO. 1 OF 1

0000103

0000104



	NASA / UNIVERSITY ADVANCED DESIGN CONCEPTS
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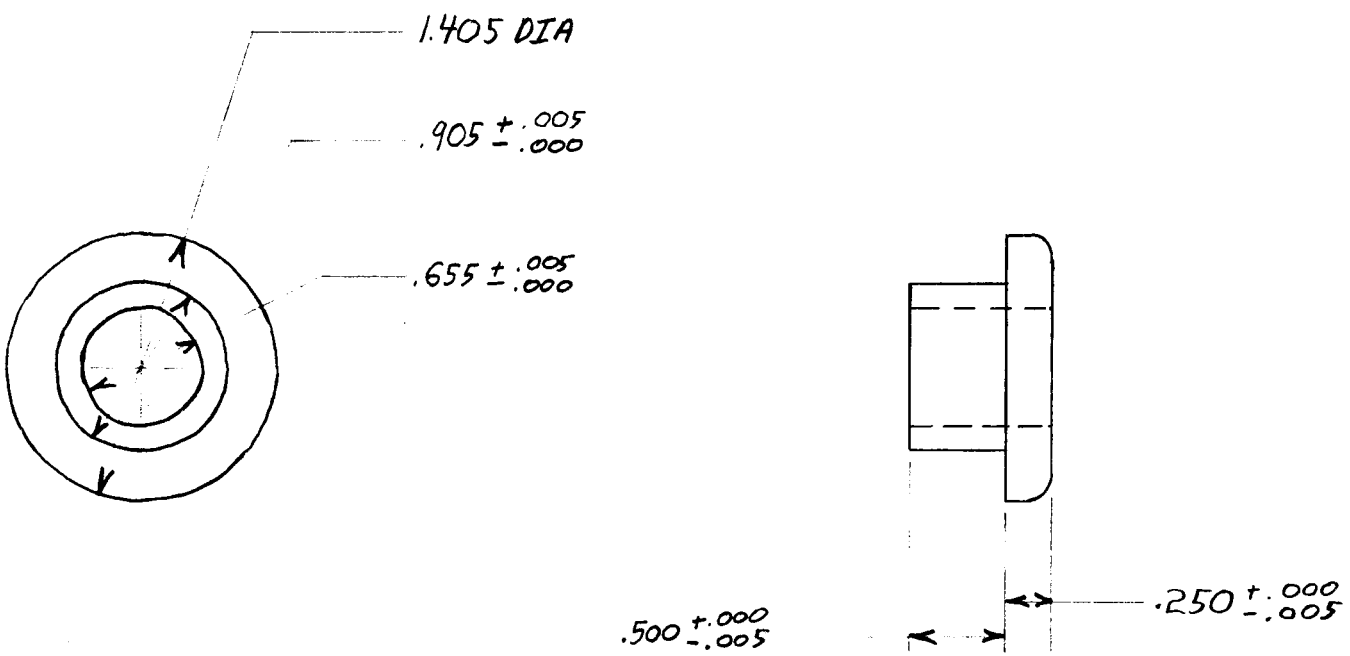
	DESIGN: No. 1 DATE: 5/30/85
MATL: COORS CERAMIC AD 90	CHECK: DATE:
SCALE: 1.00 : 1.00	DRWG NO. 1 OF 1

0000104

0000105



NASA/ UNIVERSITY ADVANCED DESIGN CONCEPTS

TOLERANCE UNLESS OTHERWISE NOTED:

IN: .100 MM:

TITLE: CERAMIC LINER - LOWER LINK, COUPLER LINK SIDE

DESIGN: No. 1 DATE: 5/30/85

MATL: COORS CERAMIC AD90

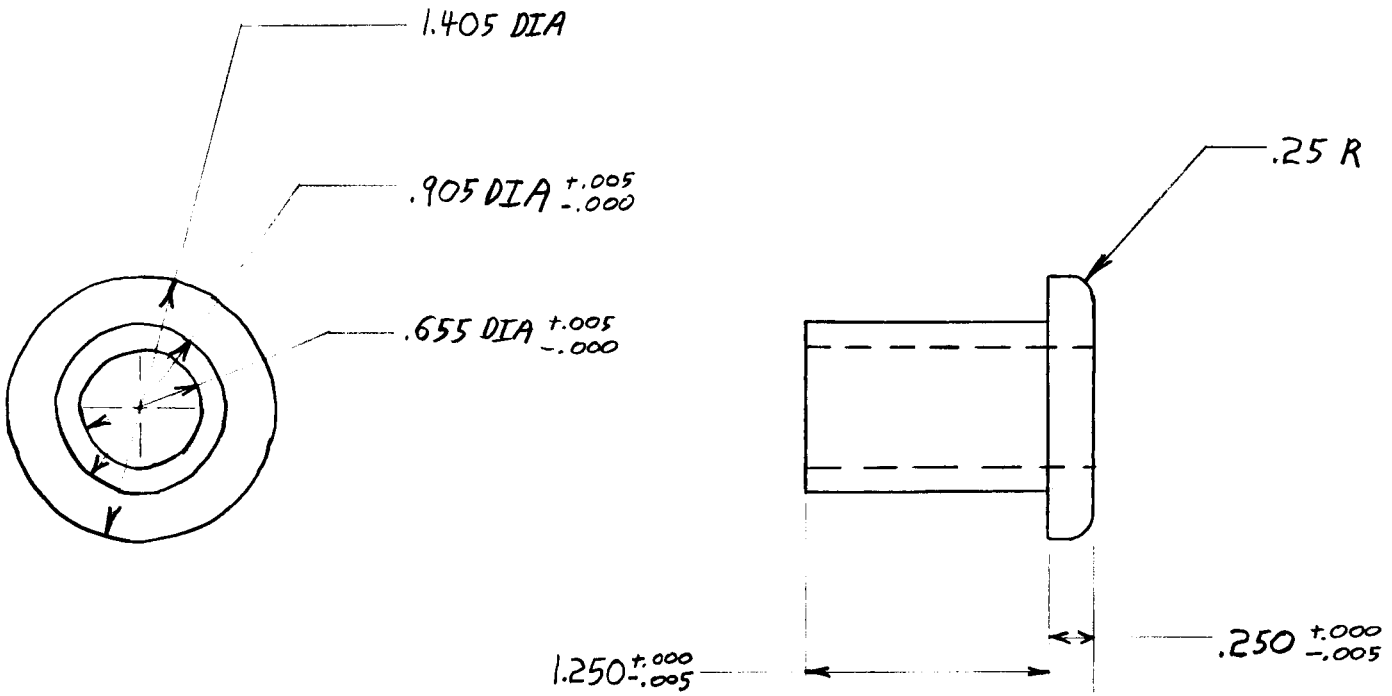
CHECK: DATE:

SCALE: 1.00 : 1.00

DRWG No. 1 OF 1

0000105.

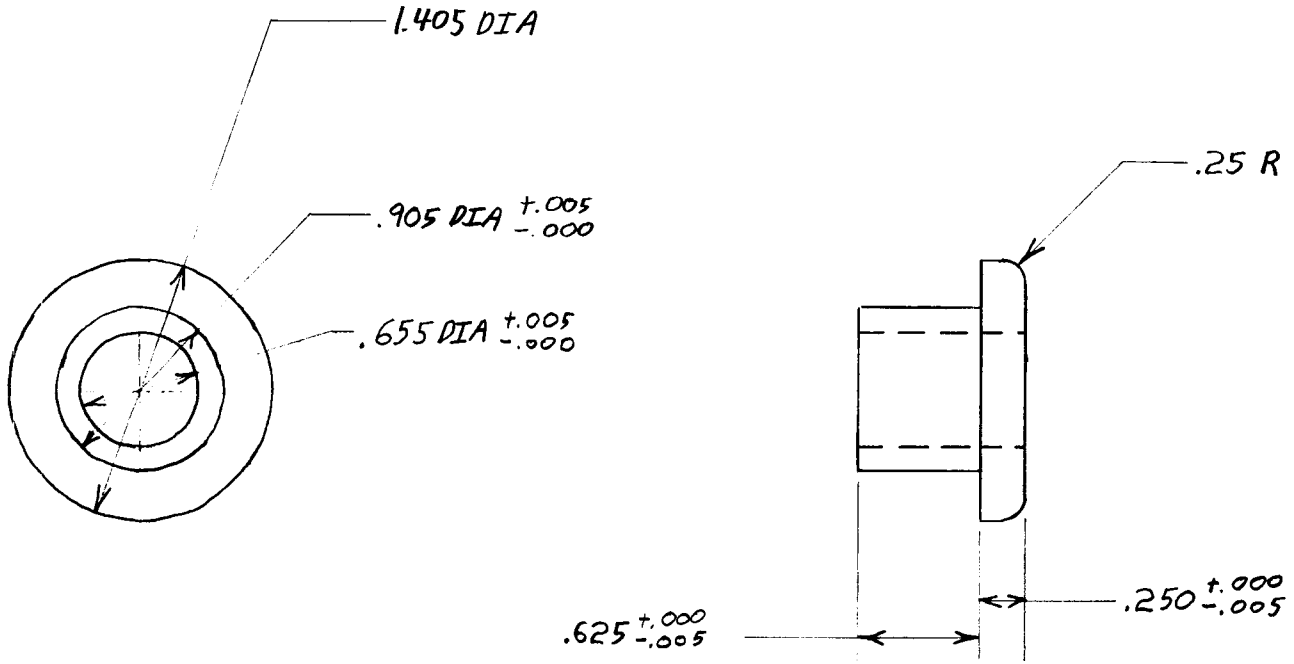
0000106



	NASA/UNIVERSITY ADVANCED DESIGN CONCEPTS
TOLERANCE UNLESS OTHERWISE NOTED:	TITLE: CERAMIC LINER - HYDRAULIC LINK, COUPLER LINK SIDE
IN: .100 MM:	DESIGN: No. 1 DATE: 5/30/85
MATL: COORS CERAMIC AD90	CHECK: DATE:
SCALE: 1.00 : 1.00	DRWG NO. 1 OF 1

0000106

0000107



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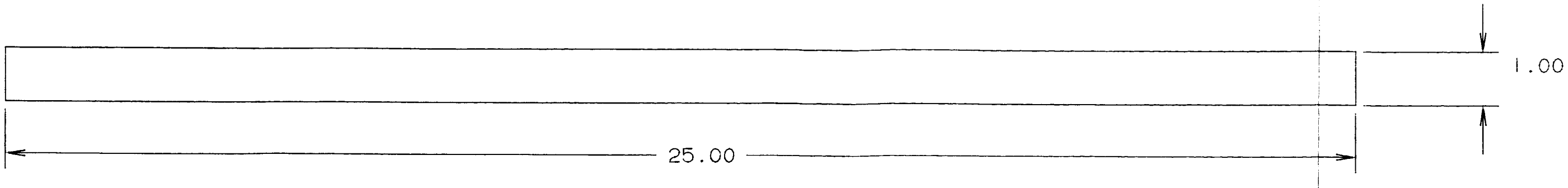
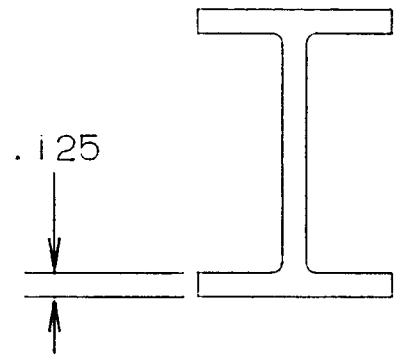
TOLERANCE UNLESS OTHERWISE NOTED:	TITLE: CERAMIC LINER - HYDRAULIC LINK, FRAME LINK SIDE
IN: .100 MM:	DESIGN: No. 1 DATE: 5/30/85
MATL: COORS CERAMIC AD 90	CHECK: DATE:
SCALE: 1.00 : 1.00	DRWG NO.: 1 OF 1

0000107

0000108





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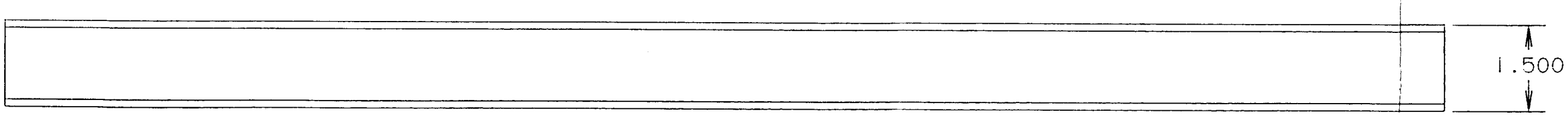
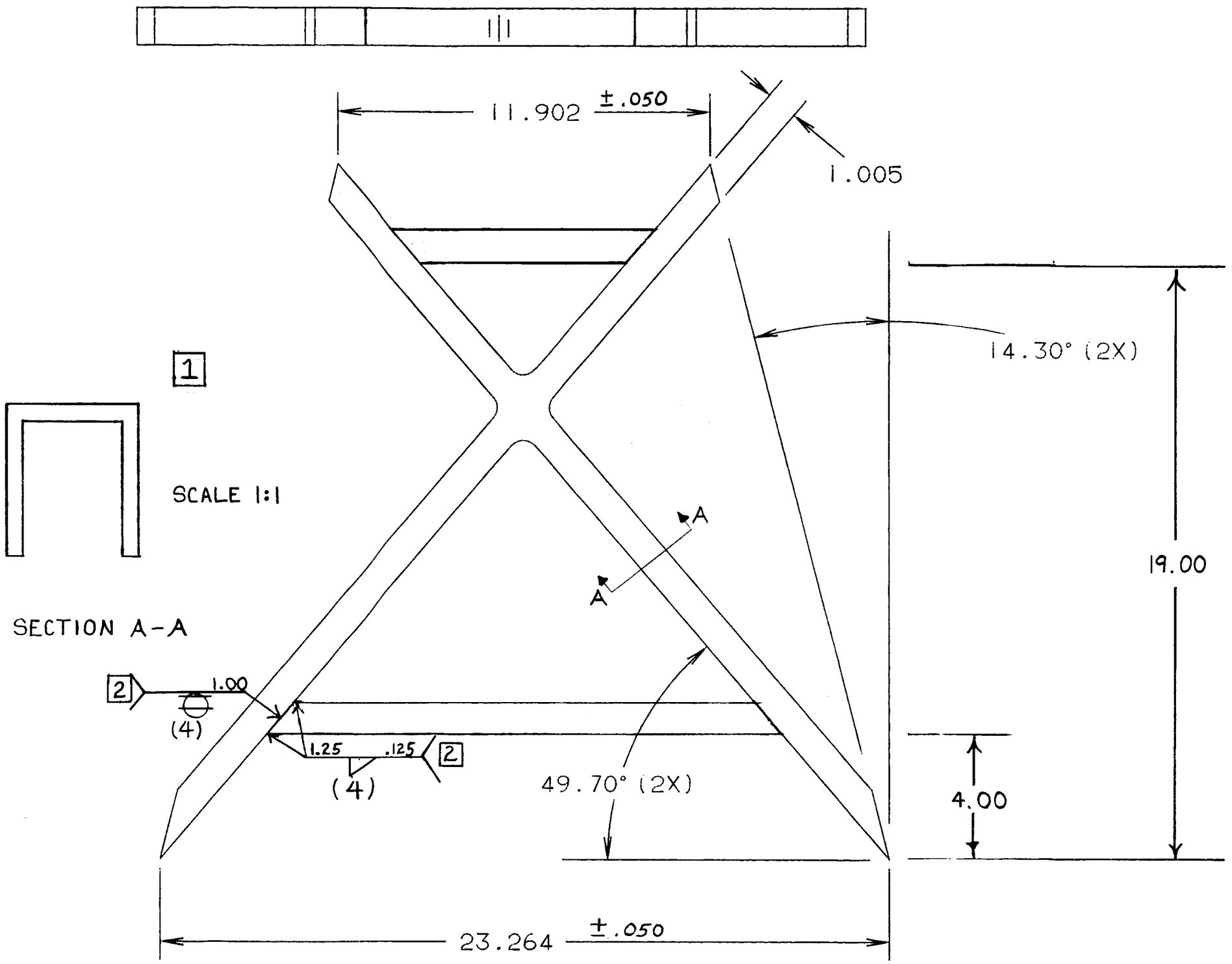


TOLERANCE UNLESS OTHERWISE NOTED:	NASA / UNIVERSITY ADVANCED DESIGN CONCEPTS
IN: .1000 MM:	TITLE: LOWER LINK
MATL: ALUMINUM 2218	DESIGN: NO. 1 DATE 5/22/85
SCALE: 0.50:1.00	CHECK: DATE
	DRWG NO. ONE

0000108

0000109



1

SCALE 1:1

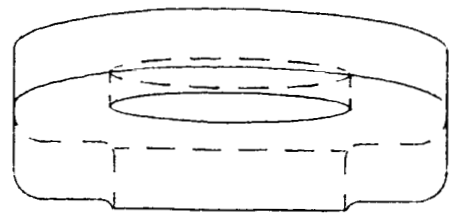
NOTES

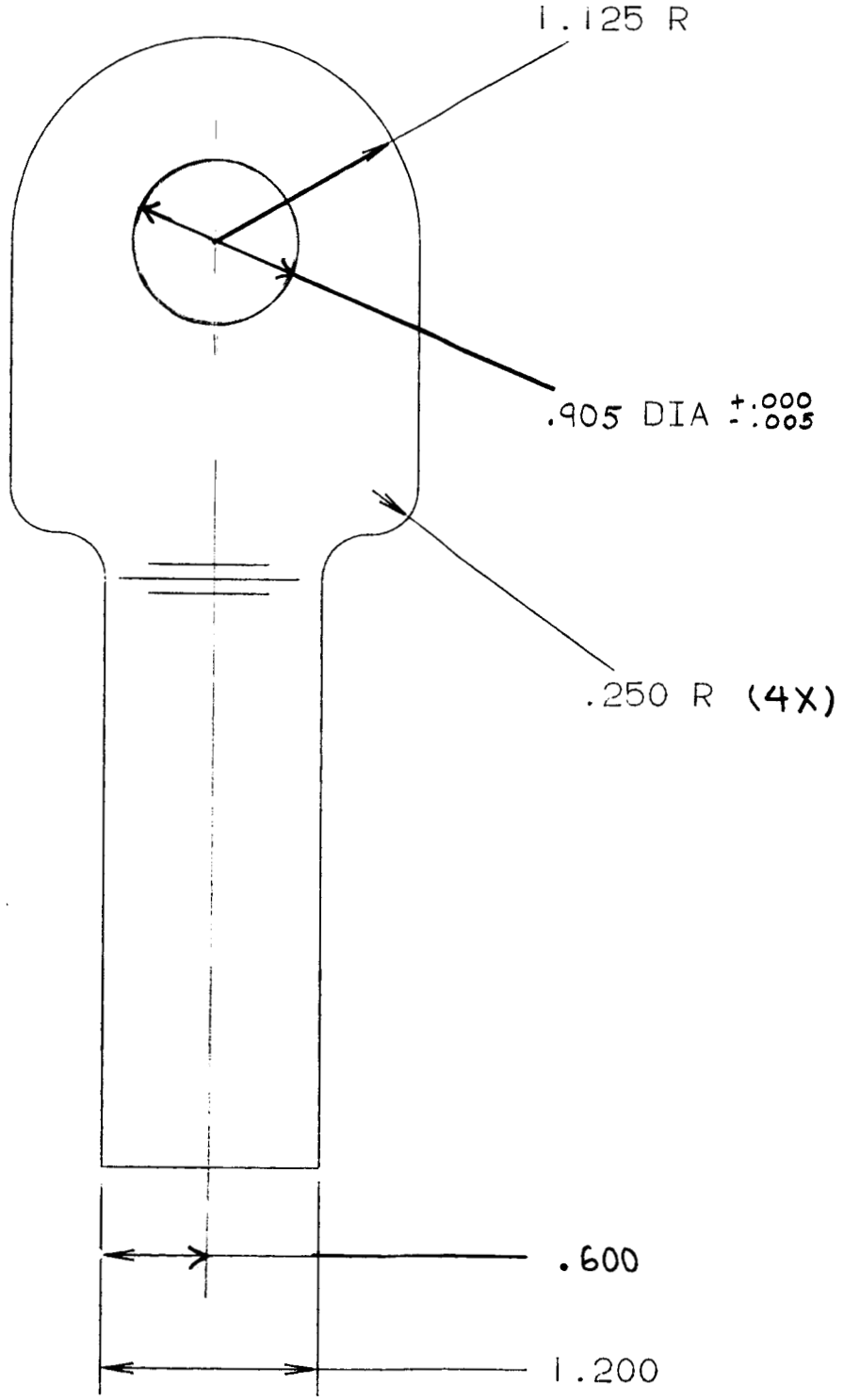
1. USE 1.0 x 1.25 x .125 ALUMINUM CHANNEL
2. USE INERT GAS CONSUMABLE ELECTRODE ARC-WELDING PROCESS

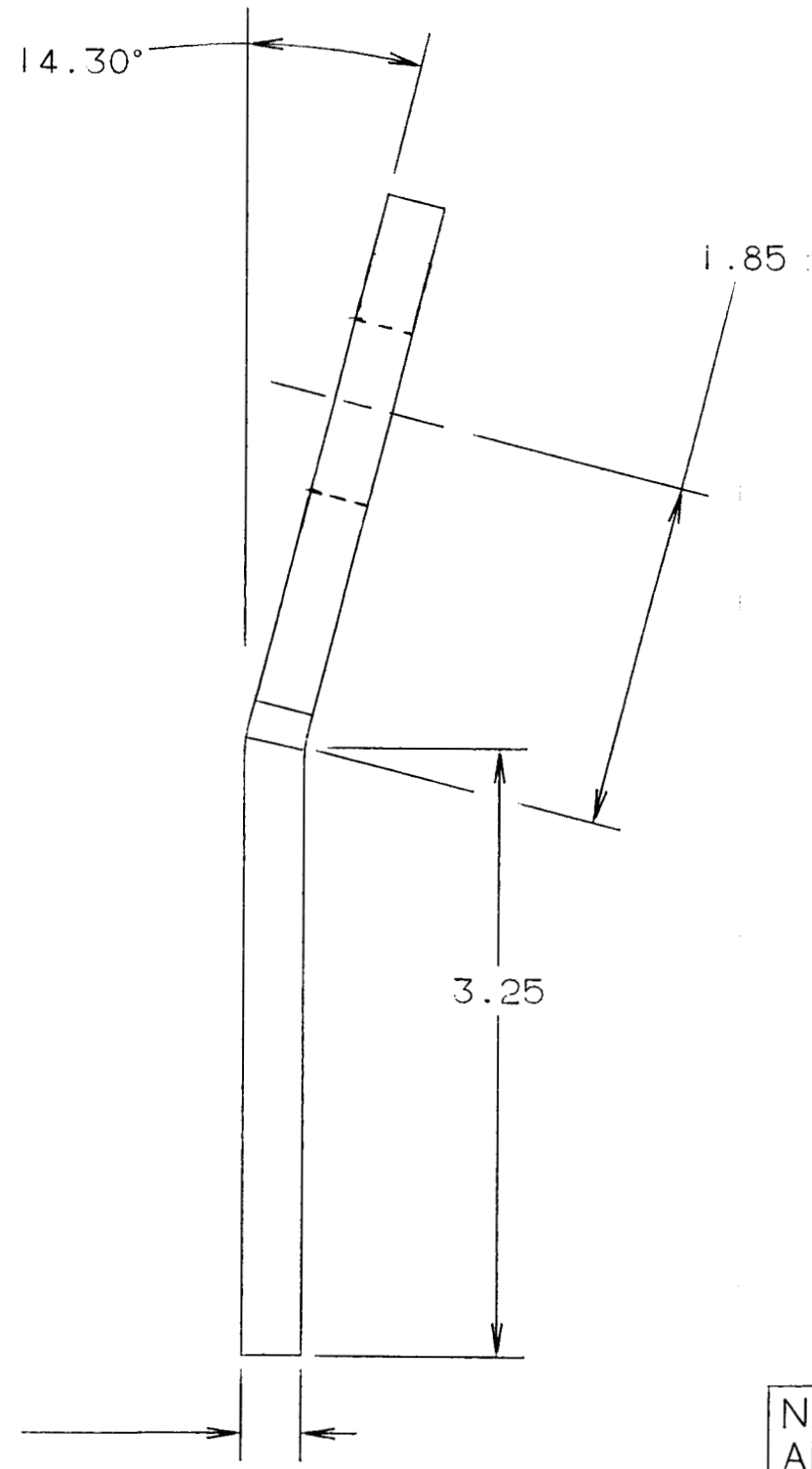
TOLERANCE UNLESS OTHERWISE NOTED:	NASA / UNIVERSITY ADVANCED DESIGN CONCEPTS
	TITLE: LOWER CROSS BRACE
IN: .100 MM:	DESIGN: No. 2 DATE 5/30/85
MATL: AL 2218	CHECK: DATE
SCALE: 0.25:1.00	DRWG NO. ONE

0000109

0000110







TOLERANCE UNLESS OTHERWISE NOTED:	NASA / UNIVERSITY ADVANCED DESIGN CONCEPTS
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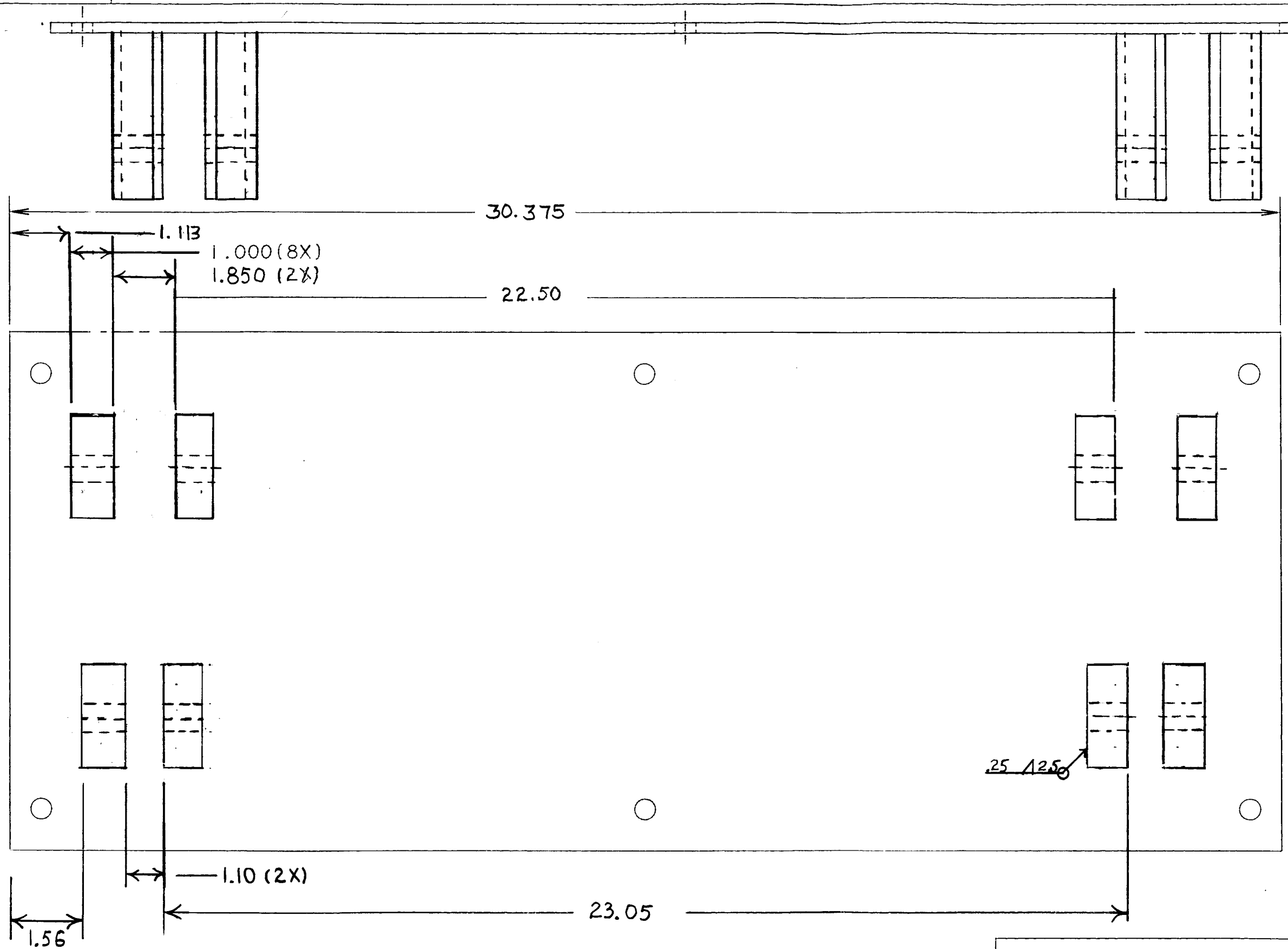
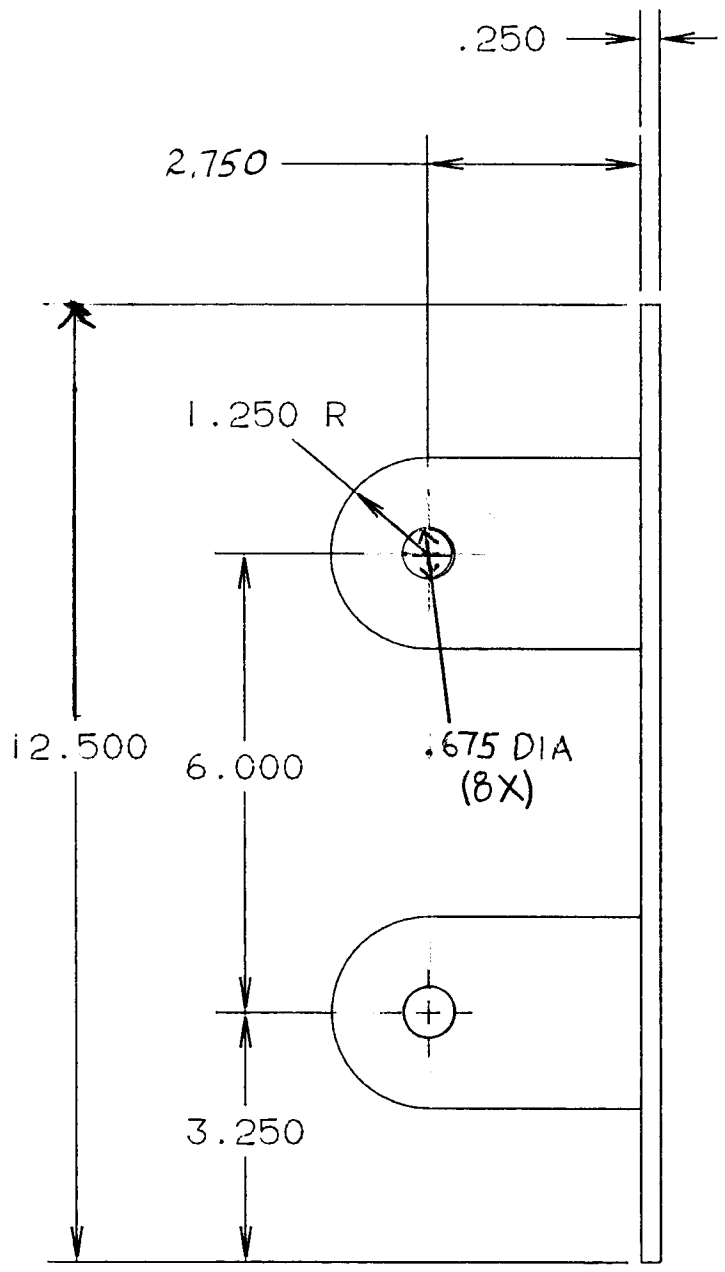
MATL: AL 2218	
SCALE: 1.00·1.00	DESIGN: NO. 2 DATE 5/31/85
	CHECK: DATE
	DRWG NO. 1 OF 1

0000110

0000111

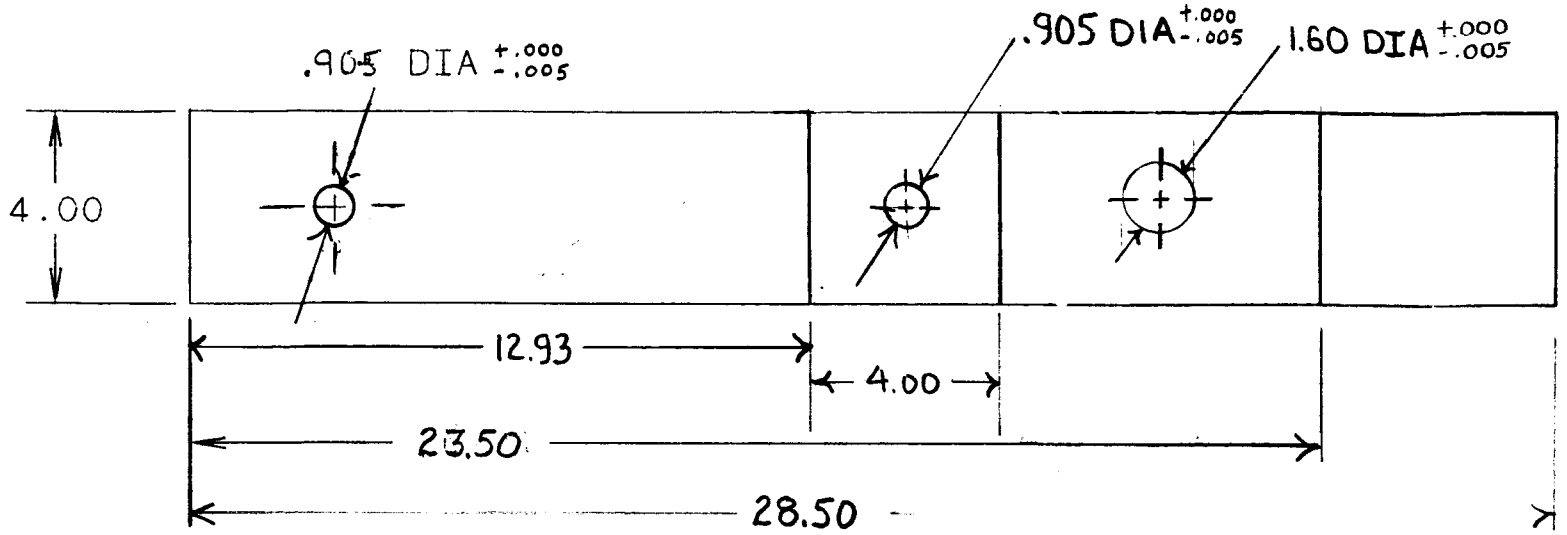


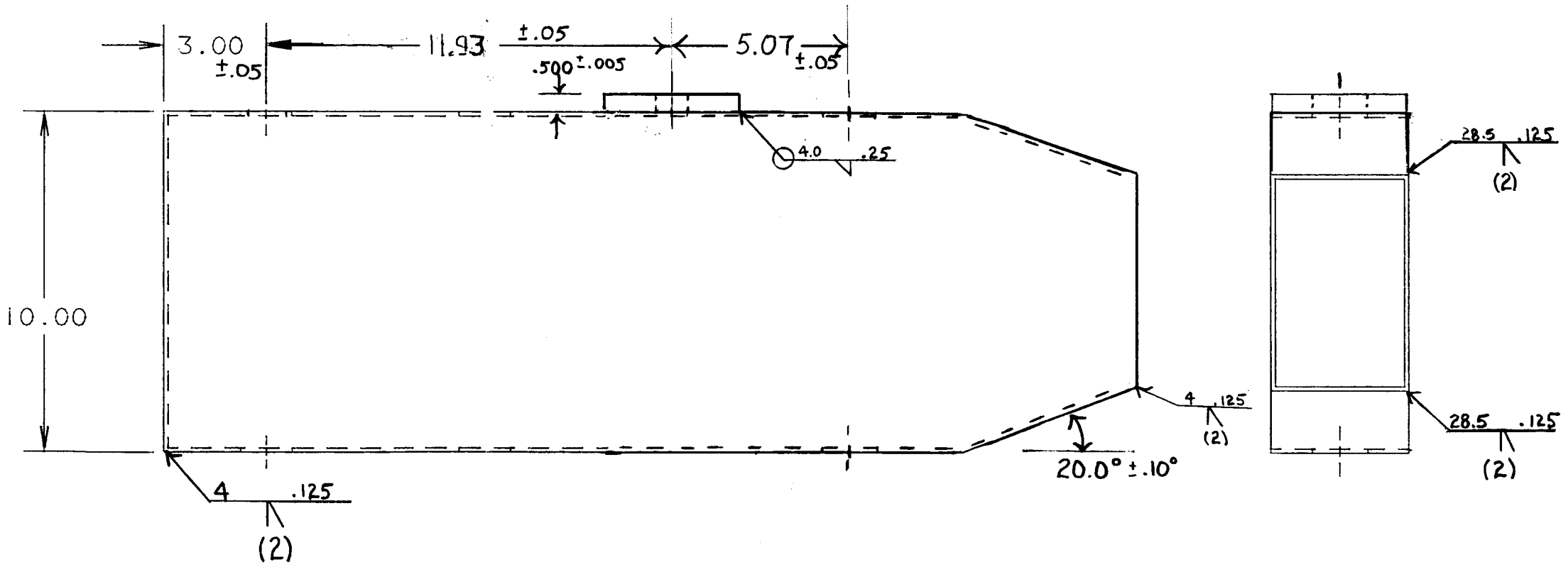


TOLERANCE UNLESS OTHERWISE NOTED:	NASA / UNIVERSITY ADVANCED DESIGN CONCEPTS
IN: .025 MM:	TITLE: MOUNTING BRACKET
MATL: AL 2218	
SCALE: .400:1	DESIGN: TWO DATE 5/30/85
	CHECK: DATE
	DRWG NO. 1 OF 1

0000111

0000112





TOLERANCE UNLESS OTHERWISE NOTED:	NASA / UNIVERSITY ADVANCED DESIGN CONCEPTS
IN: .100 MM:	TITLE: HITCH TONGUE
MATL: AL 2218	
SCALE: .250:1.00	DESIGN: ONE DATE 5/22/85
	CHECK: DATE
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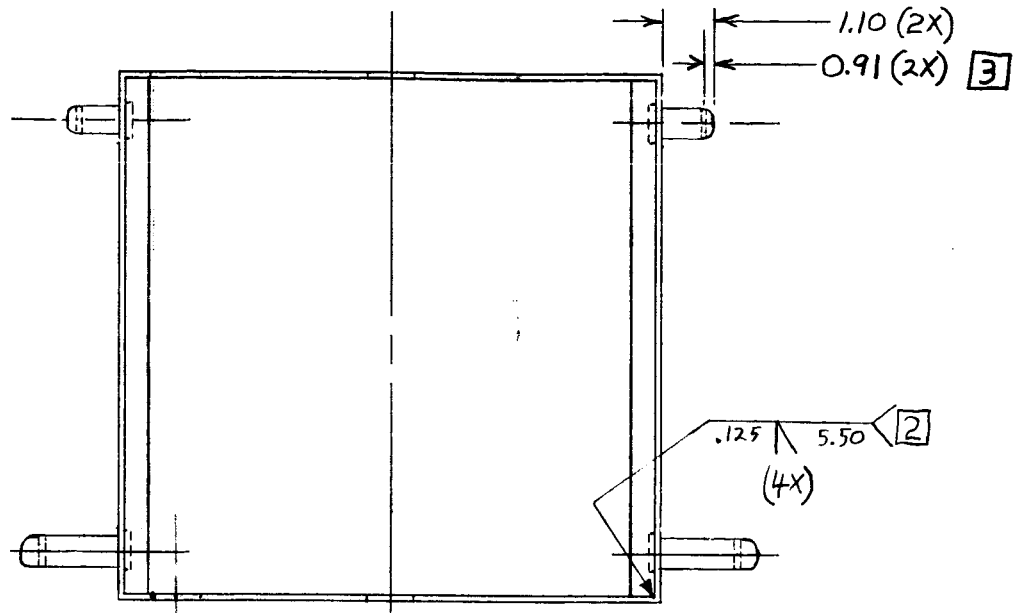
0000112

0000113



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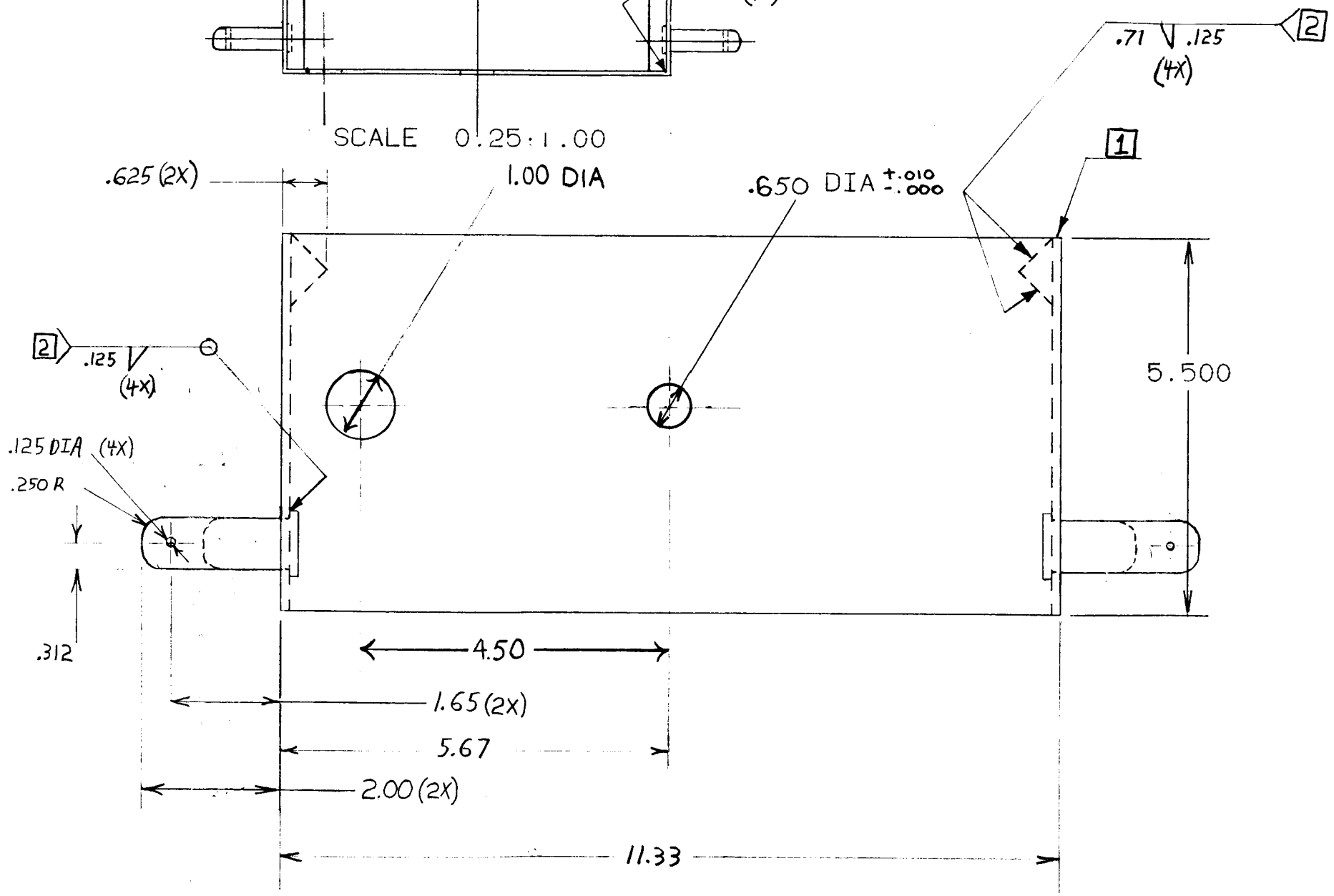
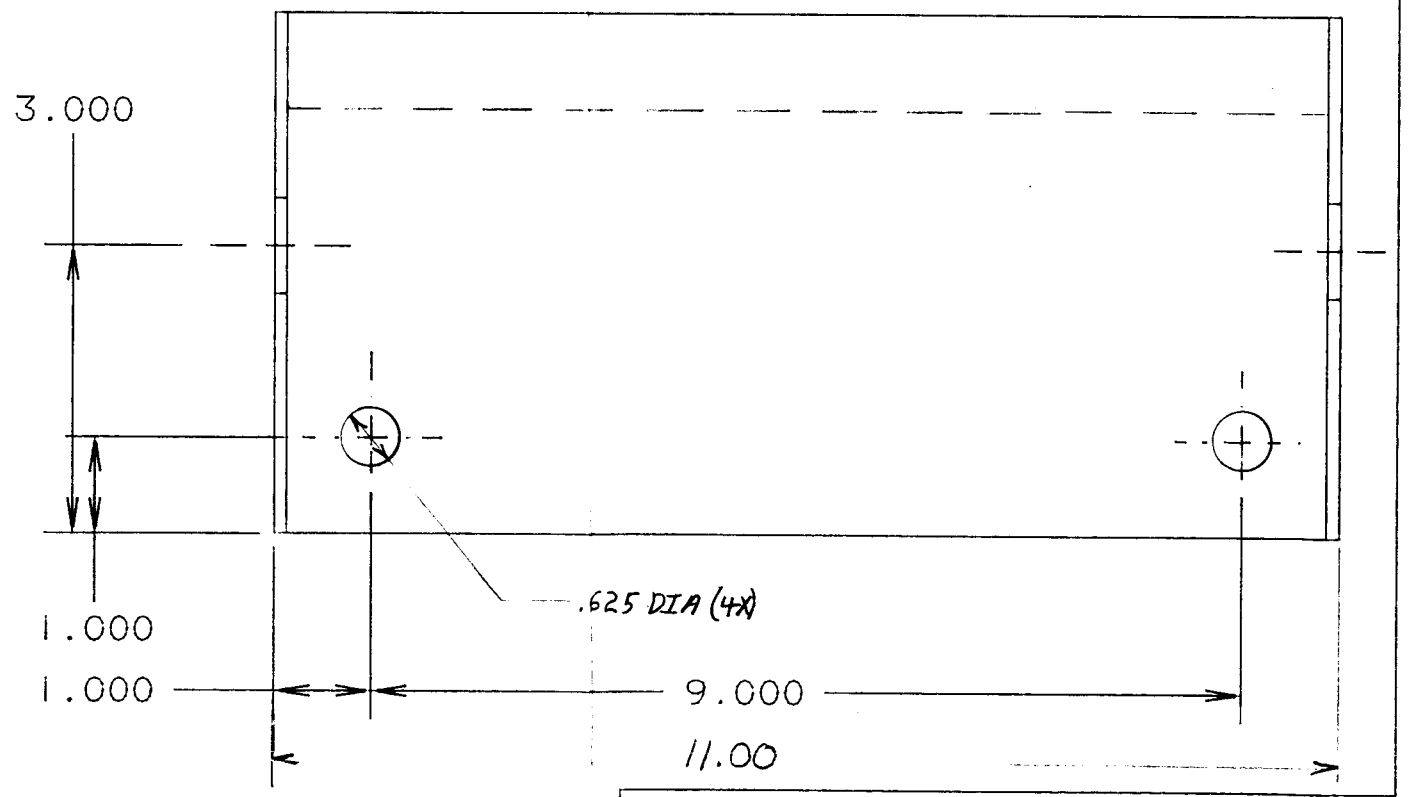




NOTES:

1. USE 1/8 in FLAT PLATE
2. INERT-GAS CONSUMABLE-ELECTRODE ARC-WELD
3. MEASUREMENT FROM CENTERLINE OF COTTER PIN HOLE

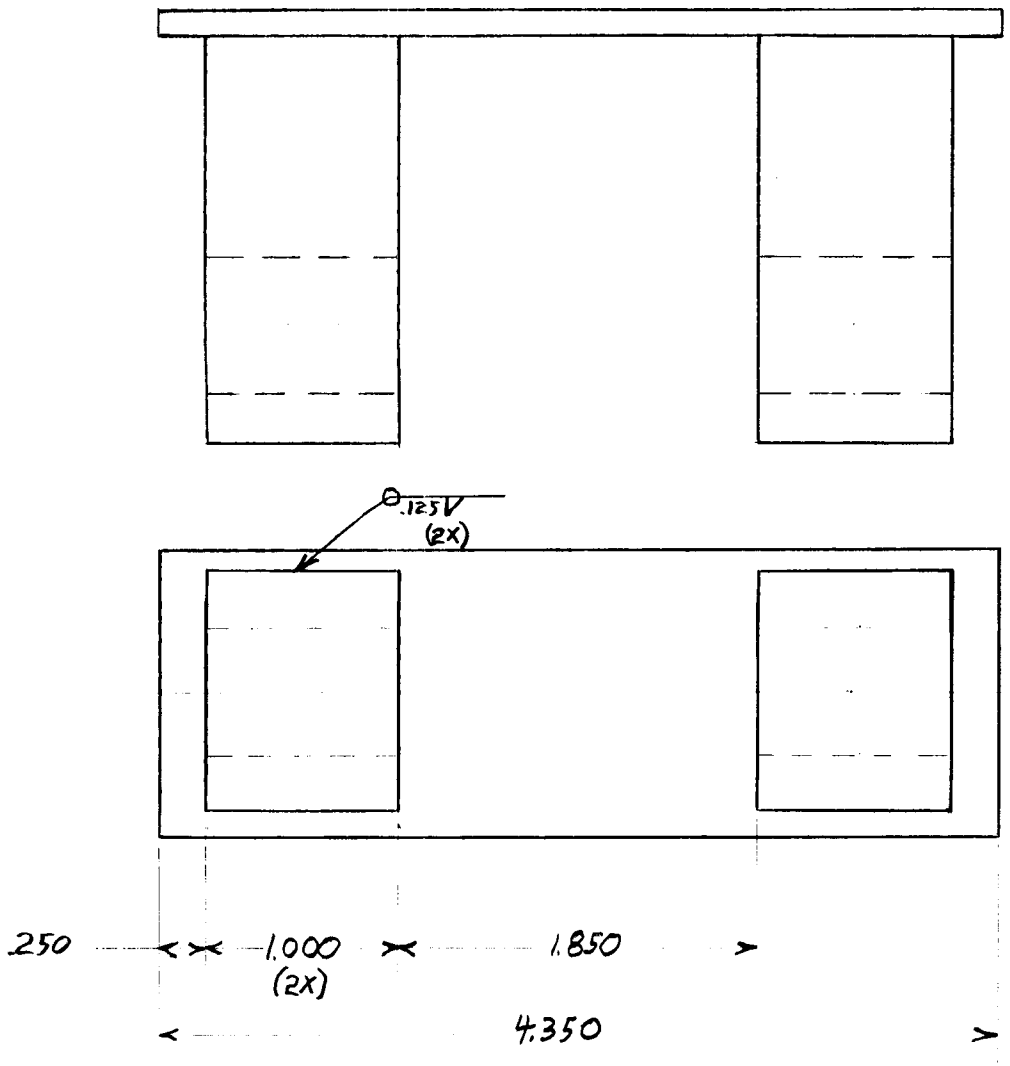
TOLERANCE UNLESS OTHERWISE NOTED:
IN: .050 MM:
MATL: AL 2218
SCALE: 0.500:1.00

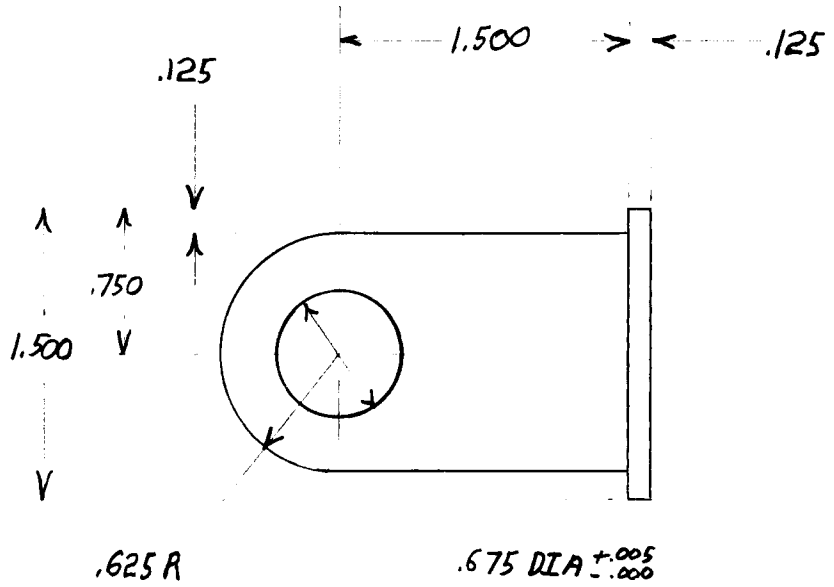
NASA / UNIVERSITY
ADVANCED DESIGN CONCEPTS

TITLE: COUPLER LINK	
DESIGN: No. 2	DATE 5/30/85
CHECK:	DATE
DRWG NO. ONE	

0000113

0000114





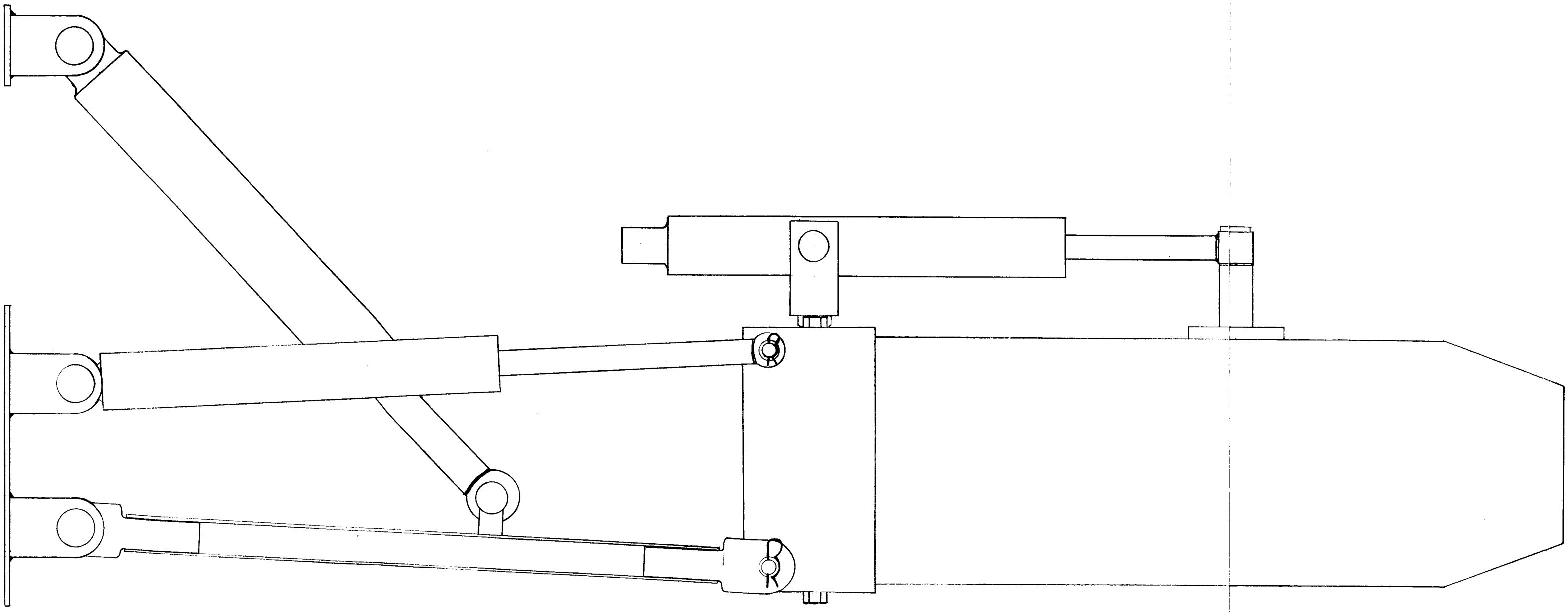
TOLERANCE UNLESS OTHERWISE NOTED	NASA/ UNIVERSITY ADVANCED DESIGN CONCEPTS
	TITLE: LIFT BRACKET
IN: .050 MM:	DESIGN: No. 1 DATE: 5/31/85
MATL: AL 2218	CHECK: DATE:
SCALE: 1.00 : 1.00	DRWG NO. 1 OF 1

0000114

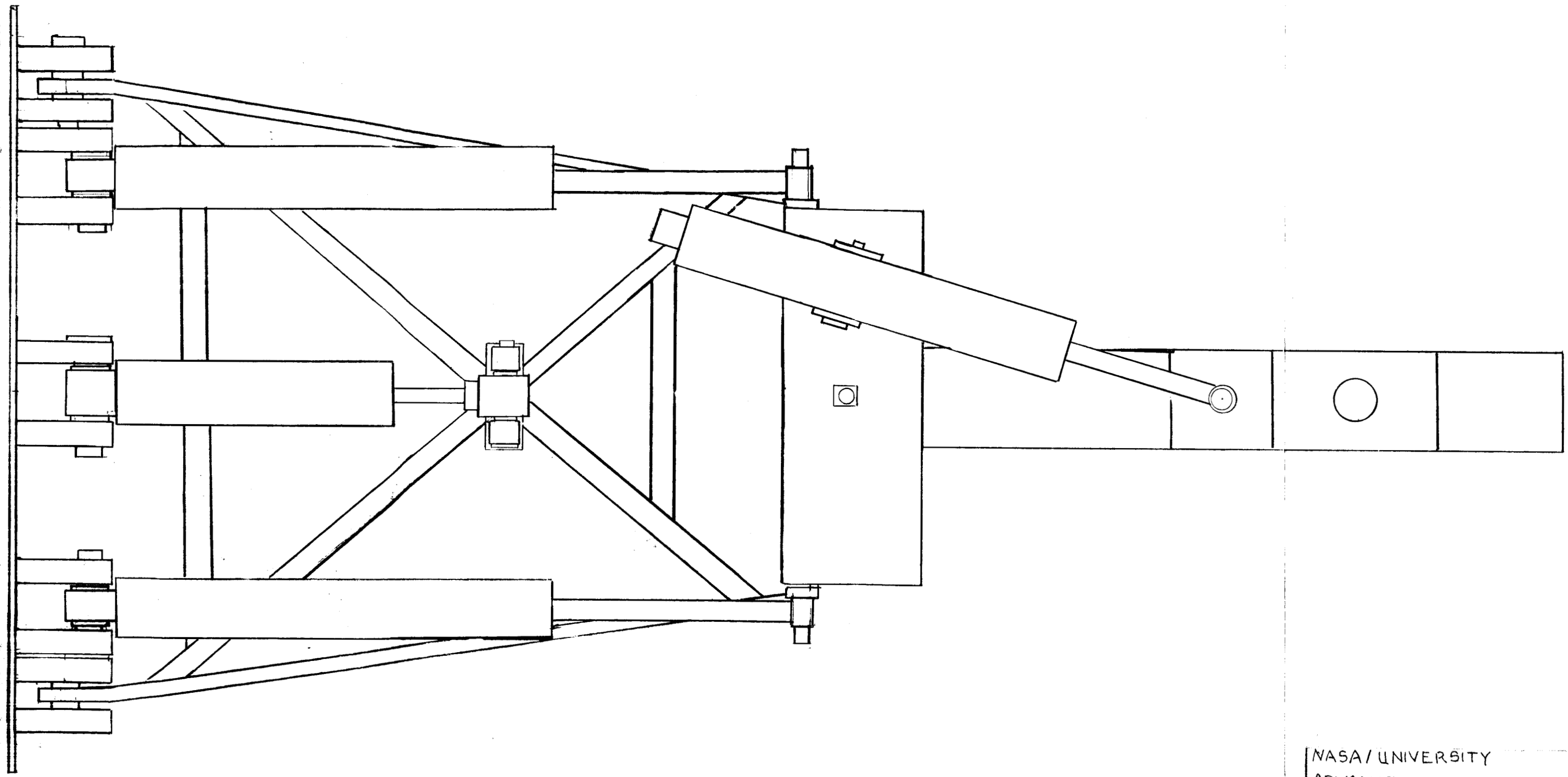
I.D. of pin = 1.00 dia

O.D. of pin = 2.00 dia

length of pin = 3.00" + to'
(from inside
shoulder)



TOLERANCE UNLESS OTHERWISE NOTED	NASA/ UNIVERSITY ADVANCED DESIGN CONCEPTS
	TITLE: ASSEMBLY DRWG - 4 BAR HITCH
IN: MM:	DESIGN: DATE: 5/31/85
MATL:	CHECK: DATE:
SCALE: 0.25 : 1.00	DRWG No



TOLERANCE UNLESS OTHERWISE NOTED

IN: MM:

MATL:

SCALE: .250 : 1

NASA / UNIVERSITY
ADVANCED DESIGN CONCEPTS

TITLE: ASSEMBLY DRAWING

DESIGN: DATE: 6-2-85

CHECK: DATE:

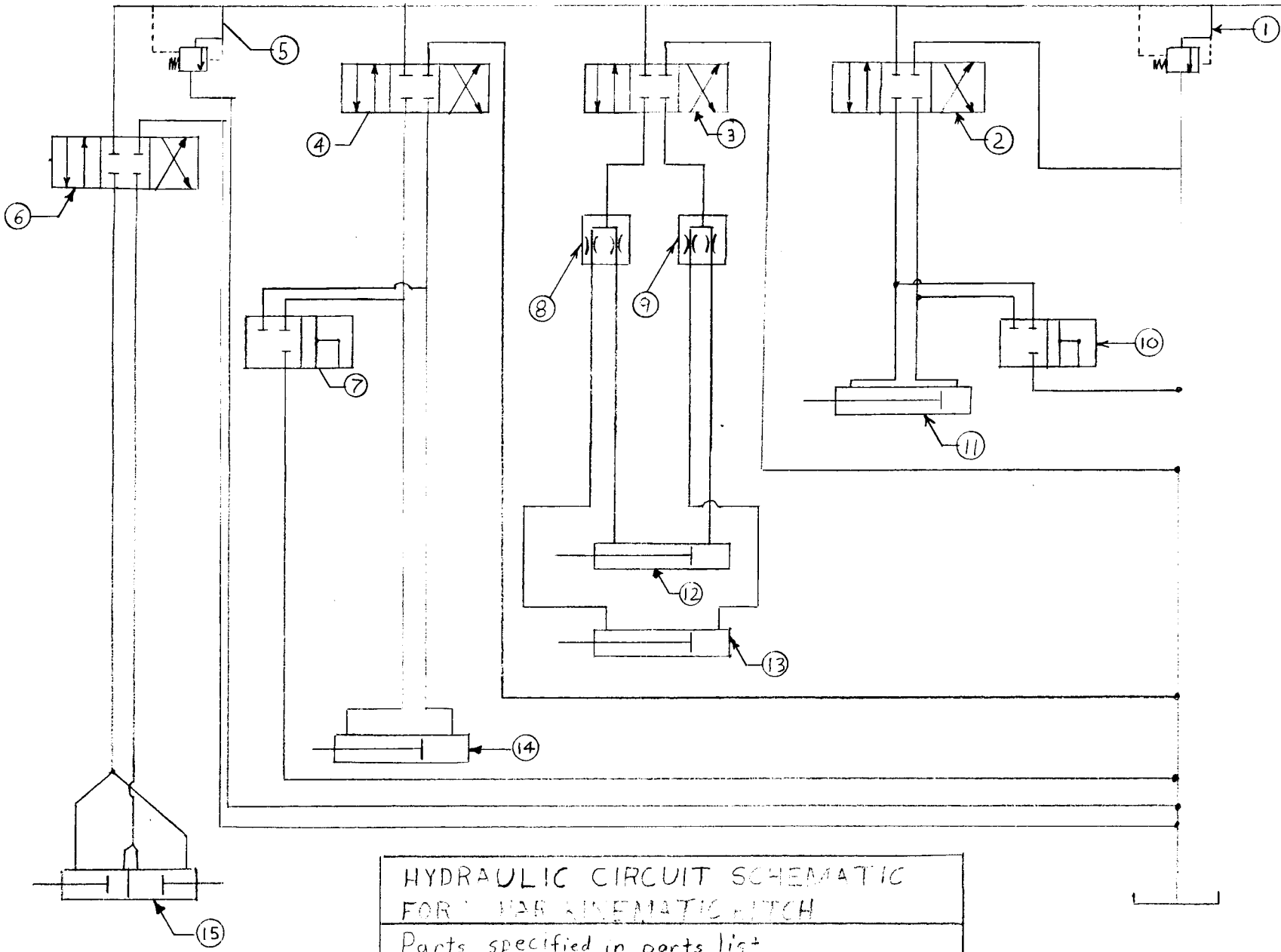
DRWG No.

NO.	MANUFACTURER	PART NUMBER	DISCRIPTION
1	Sun Hydraulic Corp.	FRDAXAVD SAE-1008	FLOW CONTROL VALVE
2	Speery Vickers	PBDG4S4-01-2C-24DC	4 Way 3-Position Directional Control Valve
3	Sperry Vickers	PBDG4S4-01-2C-24DC	4 Way 3-Position Directional Control Valve
4	Sperry Vickers	PBDG4S4-01-2C-24DC	4 Way 3-Position Directional Control Valve
5	Sun Hydraulic Corp.	FRDAXAVD SAE-1008	Flow control valve
6	Sperry-Vickers	PBDG4S4-01-2C-24DC	4 Way 3-Position Directional Control Valve
7	Speery Vickers	PBDG4S4-01-1A-24DC	4 Way 2-Positron Directional Cantrol Valve
8	Houdaille Industries	51189500	Flow Seperator
9	Houdaille Industries	51189500	Flow Seperator
10	Speery Vickers	PBDG4S4-01-1A-24DC	4 Way 2 Position Directional Control Valve
11	Benton Harbor	Series 250 3X11	Double acting Cylinder 3" bore 11" Stroke (Lift)
12	Benton Harbor	Series 250 2X12	Double acting Cylinder 2" bore 12" Stroke (Link)
13	Benton Harbor	Series 250 2X12	Double acting Cylinder 2" bore 12" Stroke (Link)
14	Viceroy		Double acting Cylinder 2" bore 12" Stroke (Rotation)
15	Custom Made		Double rod Double Acting Cylinder (Pinning)
16		WWT700/6	Piping
17	Anchor Swan	58200	Flexable hose

HYDRAULIC PARTS LIST

NO.	MANUFACTURER	PARTS NUMBER	DESCRIPTION
1	Radio Shack	275-709	Spring Centered Switch
2	Radio Shack	275-709	Spring Centered Switch
3	Radio Shack	275-709	Spring Centered Switch
4	Radio Shack	275-709	Spring Centered Switch
5	Radio Shack	275-1566	Push-Botton Switch
6	Radio Shack	275-1566	Push-Botton Switch
7	Radio Shack	275-1566	Push-Botton Switch
8	Airtronics Inc.	AL-XL 6/461	Transmitter
9	Everready		Battery
10	Airtronics	AL-92266	Receiver
11	Silicon General	SG3640P	Motor, Soleniod Amplifier

ELECTRICAL PARTS LIST

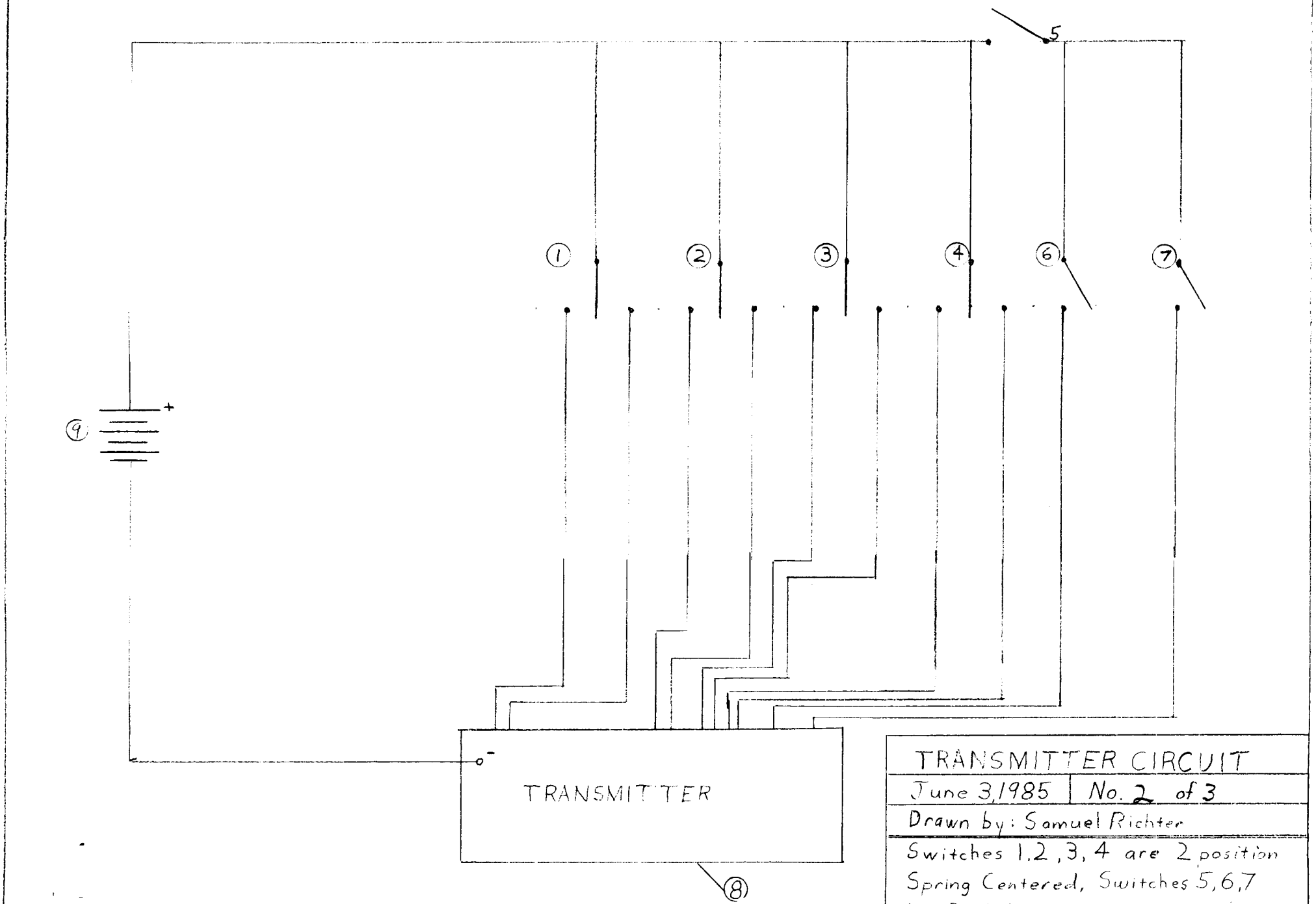


HYDRAULIC CIRCUIT SCHEMATIC
FOR [illegible] KINEMATIC HITCH

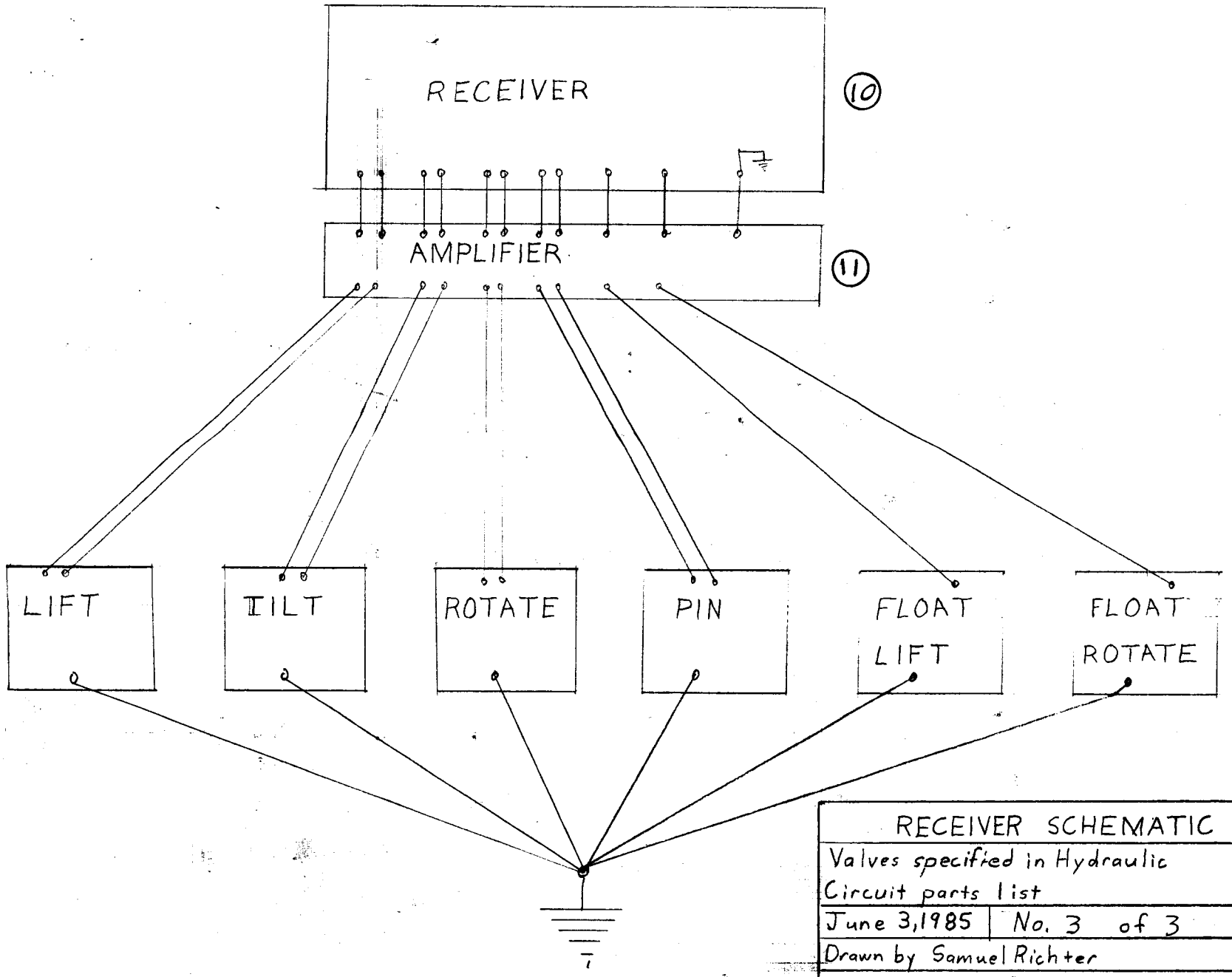
Parts specified in parts list

June 3, 1985 | No. 1 of 3

Drawn by Samuel Richter



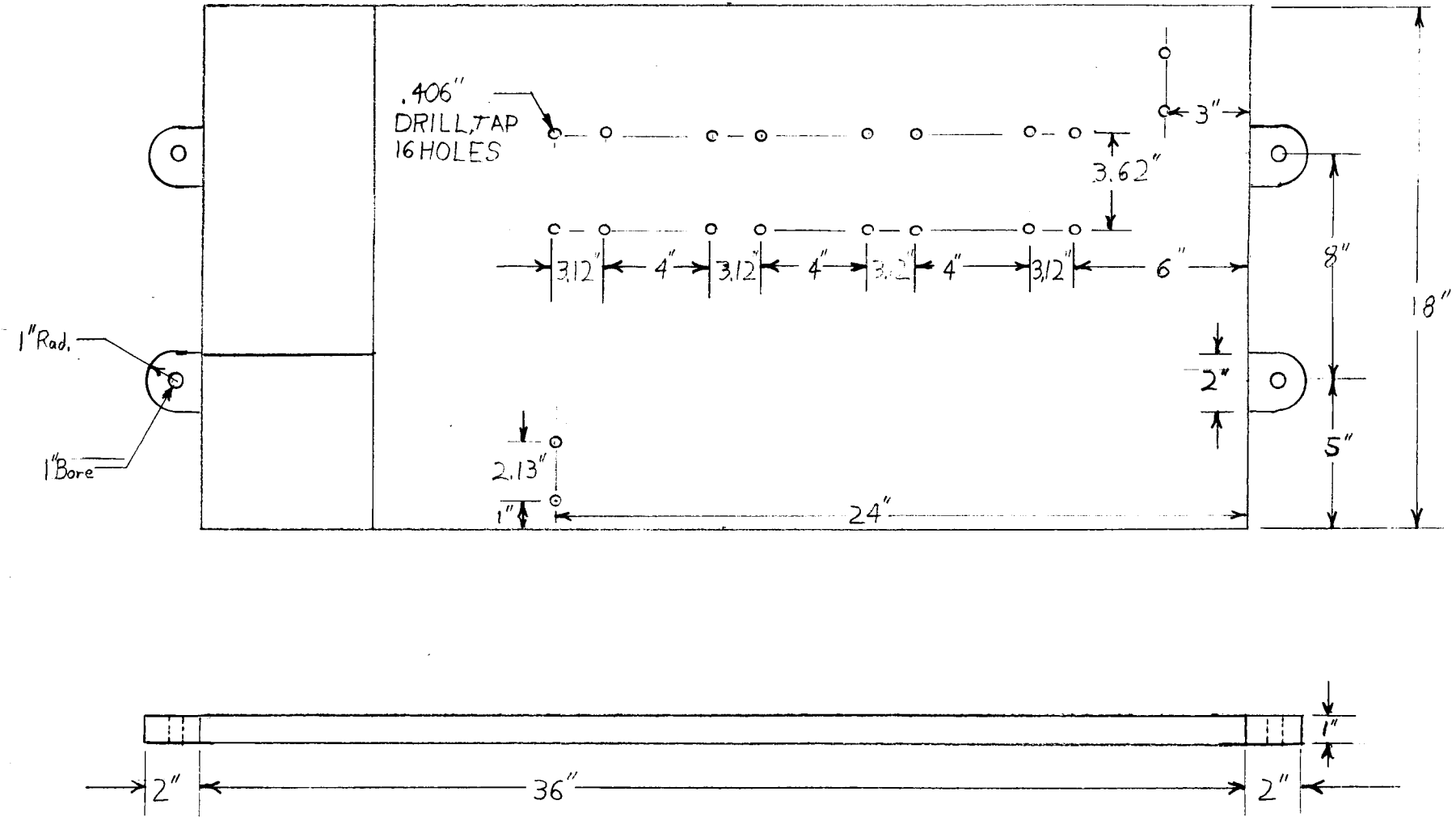
TRANSMITTER CIRCUIT	
June 3, 1985	No. 2 of 3
Drawn by: Samuel Richter	
Switches 1, 2, 3, 4 are 2 position Spring Centered, Switches 5, 6, 7 Are Push button type	

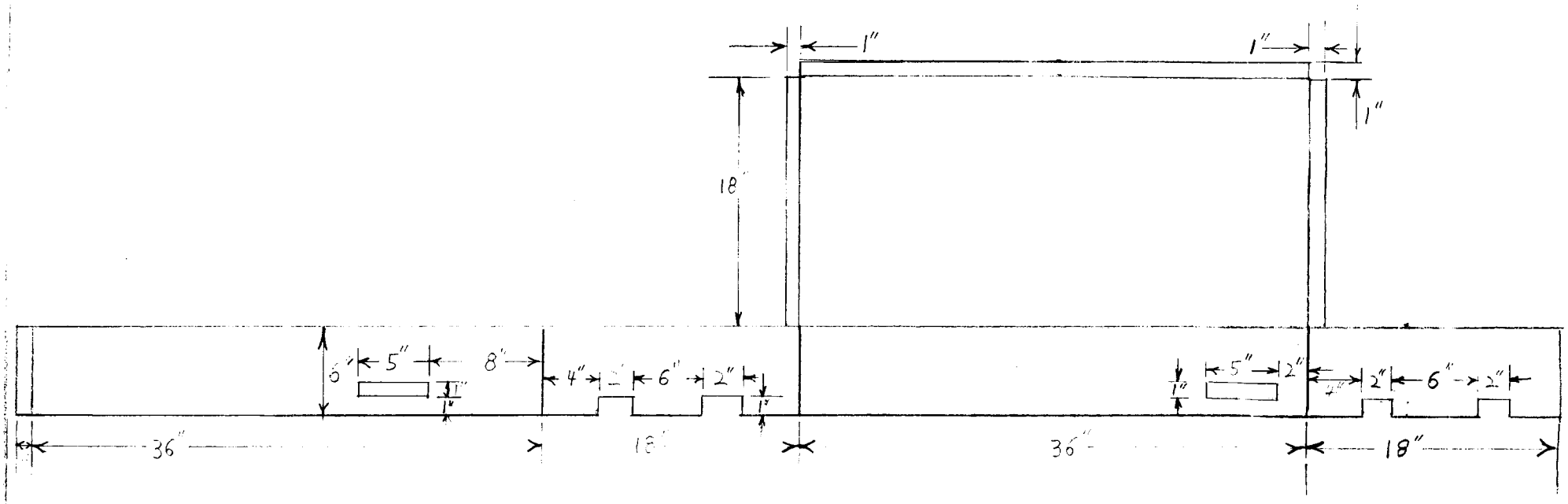


RECEIVER SCHEMATIC	
Valves specified in Hydraulic Circuit parts list	
June 3, 1985	No. 3 of 3
Drawn by Samuel Richter	

CONTROL MOUNTING PLATE

SCALE 3/16 = 1 INCH	Matl. Al
JUNE 3 1985	No. 1 of 2
Drawn by Samuel Richter	





CONTROL MOUNTING PLATE COVER	
SHEET ALUMINUM 3/32"	SCALE 3/32" = 1inch
JUNE 3, 1985	No. 1 of 2
drawn by Samuel Richter	

Punch 2 holes 5"X1"

Fold and Spot Weld